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Best Demonstrated Available Technology (BDAT) Background Document for K011 K013, and K014 (Proposed)

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PROPOSED

BEST DEMONSTRATED AVAILABLE TECHNOLOGY (BDAT)
BACKGROUND DOCUMENT FOR
K011, K013, and K014

Robert April, Chief
Treatment Technology Section

Monica Chatmon-McEaddy
Project Manager

U.S. Environmental Protection Agency
Office of Solid Waste
401 M Street, S. W.
Washington, D.C. 20460

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CHATMON-MCEADDY/APRIL/OSW

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OFFICE OF SOLID WASTE
401 M STREET, SW
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This background document provides the Agency's technical support for selecting and developing the proposed treatment standards for the constituents to be regulated in the acrylonitrile wastes. Section 2 presents waste-specific information (the number and location of facilities affected by the land disposal restrictions, the waste generating process, and waste characterization data). The technologies used to treat the waste or similar wastes are discussed in Section 3. All the available performance data, including data on which the treatment standards are based, are presented in Section 4. Section 5 explains EPA determinations of BDAT, and Section 6 discusses the selection of constitents to be regulated. The proposed treatment standards are determined in Section 7.

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1. INTRODUCTION

Pursuant to section 3004(m) of the Resource Conservation and Recovery Act as enacted by the Hazardous and Solid Waste Amendments on November 8, 1984, the Environmental Protection Agency (EPA) is proposing treatment standards based on the best demonstrated available technology (BDAT) for the wastes from the production of acrylonitrile. These wastes are identified in 40 CFR 261.32 as K011, K013, and K014. Compliance with these proposed BDAT treatment standards is a prerequisite for the placement of these wastes in units designated as land disposal facilities according to 40 CFR Part 268. The effective date of these treatment standards will be June 8, 1989.

This background document provides the Agency's technical support for selecting and developing the proposed treatment standards for the constituents to be regulated in the acrylonitrile wastes. Section 2 presents waste-specific information--the number and location of facilities affected by the land disposal restrictions, the waste generating process, and waste characterization data. The technologies used to treat the waste (or similar wastes) are discussed in Section 3. All the available performance data, including data on which the treatment standards are based, are presented in Section 4. Section 5 explains EPA's determinations of BDAT, and Section 6 discusses the selection of constituents to be regulated. The proposed treatment standards are determined in Section 7.

The BDAT program and EPA's promulgated methodology are more thoroughly described in two additional documents: Methodology for Developing BDAT Treatment Standards (USEPA 1988a) and Generic Quality

Assurance Project Plan for Land Disposal Restrictions Program (BDAT) (USEPA 1987). The petition process to be followed in requesting a variance from the proposed BDAT treatment standards is discussed in the methodology document.

The Agency has information indicating that generators of the K011, K013, and K014 listed wastes currently mix them together before treatment and disposal. Consequently, EPA has developed proposed treatment standards for these wastes as K011/K013/K014 mixed wastewaters and K011/K013/K014 mixed nonwastewaters. However, each individual waste, if disposed of separately, must also meet the proposed treatment standards. (For the purpose of determining the applicability of the proposed treatment standards, wastewaters are defined as wastes containing less than 1 percent (weight basis) total suspended solids* and less than 1 percent (weight basis) total organic carbon (TOC). Waste not meeting this definition must comply with the proposed treatment standards for nonwastewaters.)

The acrylonitrile wastes contain cyanide and BDAT list organic and metal constituents. Rotary kiln incineration was determined to be the BDAT for the organics and cyanides in the K011/K013/K014 nonwastewaters; this technology generates an ash residual that may require metals treatment. The BDAT for the ash residual is stabilization. For the cyanides present in the K011/K013/K014 wastewaters, wet air oxidation was determined to be the BDAT. Wet air oxidation followed by biological treatment was determined to be the BDAT for the organics in the K011/K013/K014 wastewaters. For the metals present in the wastewaters, lime precipitation followed by vacuum filtration was determined to be the BDAT.

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*The term "total suspended solids" (TSS) clarified EPA's previously used terminology of "total solids" and "filterable solids." Specifically, total suspended solids is measured by Method 209c. (Total Suspended Solids Dried at 103 to 105°C) in Standard Methods for the Examination of Water and Wastewater, 16th Edition (APHA, AWWA, and WPCF 1985).

The Agency is proposing to regulate four organic constituents, one metal constituent, and cyanide in both nonwastewater and wastewater forms of the acrylonitrile wastes. One of the organic constituents proposed for regulation, acrylamide, may be added to the BDAT list of constituents. The Agency feels that acrylamide is an important constituent for regulation of the acrylonitrile wastes because it is toxic and has been identified in the K011, K013, and K014 waste streams in high concentrations. A high-performance liquid chromatography (HPLC) method was used to perform acrylamide analysis on both wastewater and nonwastewater samples. Testing procedures for all sample analyses performed for the regulated constituents are specifically identified in Appendix A of this background document.

For the BDAT list organics and cyanide, the proposed treatment standards reflect total waste concentration. The units for the total waste concentration are mg/kg (parts per million on a weight-by-weight basis) for nonwastewaters and mg/l (parts per million on a weight-by-volume basis) for wastewaters. For BDAT list metals in nonwastewaters, the proposed treatment standards reflect the leachate concentration from the TCLP. The units for the leachate concentration are mg/l. For BDAT list metals in wastewaters, the proposed treatment standards reflect the total waste concentration and the units are mg/l. The proposed treatment standards for the K011/K013/K014 wastewater and nonwastewater forms are shown in Table 1-1. Wastes that, as generated, contain the regulated constituents at concentrations that do not exceed the proposed treatment standards are not prohibited from land disposal units.

EPA wishes to point out that, because of facility claims of confidentiality, this document does not contain all of the data that EPA used in its regulatory decision-making process. Under 40 CFR Part 2, Subpart B, facilities may claim any or all of the data that are submitted to EPA as confidential. Any determinations regarding the validity of the facility's claim of confidential business information (CBI) will be made by EPA according to 40 CFR Part 2, Subpart B. In the meantime, the Agency will treat the data as CBI. Additionally, the Agency would like to emphasize that all the data evaluated for the development of the proposed BDAT treatment standards for K011/K013/K014 wastewaters and nonwastewaters have been evaluated according to the BDAT methodology. All deletions of confidential business information (CBI) are noted in the appropriate places in this background document.

Table 1-1 Proposed BDAT Treatment Standards

BDAT Treatment Standards for K011/K013/K014 Nonwastewaters

Constituent	Maximum for any single grab sample Total composition (mg/kg)	 TCLP (mg/l)
Acetonitrile	1.8	Not Applicable
Acrylonitrile	1.4	Not Applicable
Acrylamide	23	Not Applicable
Benzene	0.03	Not Applicable
Cyanides (Total)	57	Not Applicable
Nickel	Not Applicable	0.32

BDAT Treatment Standards for K011/K013/K014 Wastewaters

Constituent	Maximum for any single grab sample Total composition (mg/l)	 TCLP (mg/l)
Acetonitrile	0.14	Not Applicable
Acrylonitrile	0.14	Not Applicable
Acrylamide	0.14	Not Applicable
Benzene	0.14	Not Applicable
Cyanides (Total)	12	Not Applicable
Cyanides (Amenable)	1.3	Not Applicable
Nickel	0.44	Not Applicable

2. INDUSTRY AFFECTED AND WASTE CHARACTERIZATION

The purposes of this section are to describe the industry that will be affected by the land disposal restrictions for waste codes K011, K013, and K014 and to characterize these wastes to help support the rationale for the selection of BDAT. This section includes a description of the industry affected and the production processes employed in this industry. Also included is a discussion of how K011, K013, and K014 wastes are generated as well as characterization of the individual K011, K013, and K014 wastes and the K011/K013/K014 mixed wastes. This section concludes with a discussion of the basis for combining listed acrylonitrile waste codes into one treatability group.

The full list of hazardous waste codes from specific sources is given in 40 CFR 261.32. Within this list, three specific hazardous waste codes are generated by acrylonitrile manufacturers:

K011: Bottom stream from the wastewater stripper in the production of acrylonitrile.

K013: Bottom stream from the acetonitrile column in the production of acrylonitrile.

K014: Bottoms from the acetonitrile purification column in the production of acrylonitrile.

2.1 Industry Affected and Process Description

The four-digit standard industrial classification (SIC) code reported for the acrylonitrile industry is 2869. The Agency has identified six facilities in the United States that are actively involved in the manufacture of acrylonitrile and could generate K011, K013, and K014 listed wastes (Standford Research Institute 1988). Of the six acrylonitrile manufacturers, one is located in Ohio (EPA Region V), one in Louisiana (EPA Region VI), and four in Texas (EPA Region VI).

Acrylonitrile is manufactured in the United States by the Sohio Process. This process involves vapor-phase catalytic air oxidation of propylene and ammonia, also known as ammoxidation, to yield acrylonitrile. The principal byproducts of the process are hydrogen cyanide, acetonitrile, and acrylamide. The process flow diagram is illustrated in Figure 2-1. Approximate stoichiometric quantities of propylene, ammonia, and oxygen (as air) are reacted in a fluidized bed reactor to yield acrylonitrile and other byproducts. The gaseous effluents from the reactor are quenched and scrubbed in a quenching column using sulfuric acid solution. Unreacted ammonia is converted to soluble ammonium sulfate in the presence of sulfuric acid. Liquid effluents from the quench column are treated in a wastewater stripping column to recover the low boiling point organics. The bottom stream from the stripping column constitutes one of the listed wastes (K011). Typical generation rates for this waste stream vary from 100 to 200 gallons per minute.

Gaseous effluents from the quench column are sent to an absorber, where the acrylonitrile and byproducts are absorbed in water. The aqueous solution from the absorber is treated in an acrylonitrile recovery column to obtain acrylonitrile and hydrogen cyanide (HCN) as the overhead products. The overhead products are treated further in a heads

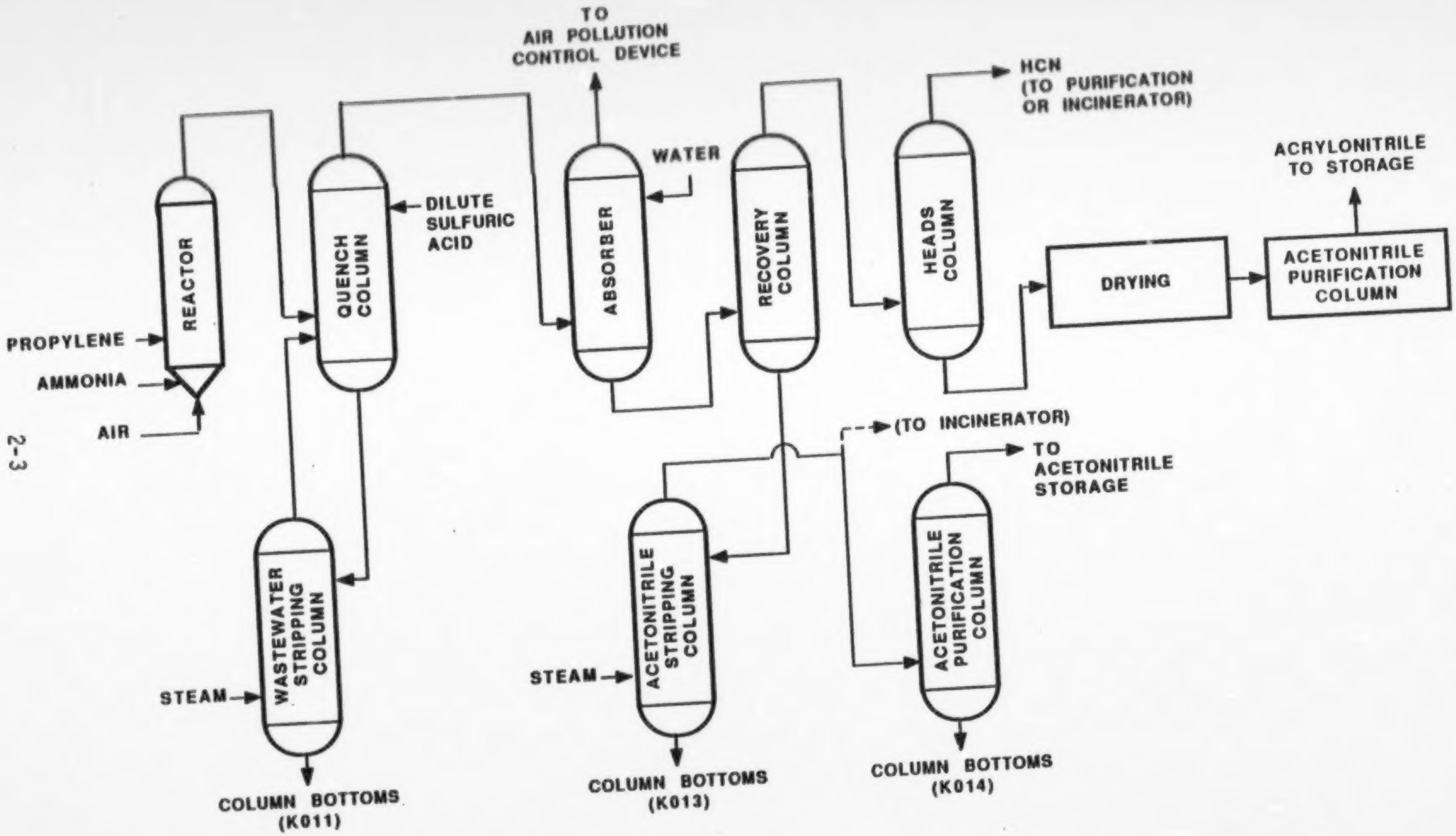
TO AIR POLLUTION CONTROL DEVICE
HCN (TO PURIFICATION OR INCINERATOR)
ACRYLONITRILE TO STORAGE
WATER
DILUTE SULFURIC ACID
PROPYLENE
AMMONIA
AIR
REACTOR
QUENCH COLUMN
ABSORBER
RECOVERY COLUMN
HEADS COLUMN
DRYING
ACETONITRILE PURIFICATION COLUMN
(TO INCINERATOR)
TO ACETONITRILE STORAGE
STEAM
WASTEWATER STRIPPING COLUMN
STEAM
ACETONITRILE STRIPPING COLUMN
ACETONITRILE PURIFICATION COLUMN
COLUMN BOTTOMS (K011)
COLUMN BOTTOMS (K013)
COLUMN BOTTOMS (K014)

FIGURE 2-1. SCHEMATIC FLOW DIAGRAM OF THE SOHIO PROCESS FOR PRODUCTION OF ACRYLONITRILE

column to recover hydrogen cyanide. The acrylonitrile bottom stream from the heads column is dried and purified further to yield polymer-grade acrylonitrile.

The bottom stream from the recovery column consists of a dilute aqueous solution of acetonitrile, which is treated in a steam stripping column to obtain acetonitrile and hydrogen cyanide as the overhead products. The bottom stream from this column constitutes a listed waste stream (K013). Typical generation rates for this stream vary from 100 to 200 gallons per minute. Depending upon the demand for acetonitrile, some acrylonitrile production plants treat the crude acetonitrile stream in a purification column to obtain commercial-grade acetonitrile. The bottoms from the acetonitrile purification column represents the third listed waste stream (K014). Typical generation rates for this stream vary from 5,000 to 20,000 gallons per day. In acrylonitrile production facilities where the acetonitrile is not refined, the crude acetonitrile stream is usually incinerated in an off-gas incinerator, thus eliminating the generation of K014.

2.2 Waste Characterization

The waste streams are identified in Figure 2-1. The listing constituents for K011, K013, and K014 include acrylonitrile, acetonitrile, and hydrocyanic acid. The approximate percent concentrations of major constituents making up individual K011, K013, and K014 listed wastes, K011/K013/K014 wastewater mixtures, and K011/K013/K014 nonwastewater mixtures are presented in Table 2-1 at the end of this section.

The K011 waste stream represents the largest single pollutant load within the acrylonitrile production process. Typically, the K011 waste stream contains about 100 to 4,000 ppm of cyanide, 40 to 3,000 ppm of acetonitrile, 0.2 to 8,000 ppm of acrylonitrile, 1,000 to 2,000 ppm of acrylamide, and less than 200 ppm of acrolein. In addition to the primary contaminants listed above, this stream also contains approximately 4 percent suspended solids. The suspended solids consist largely of spent, inorganic catalyst particles and polymeric acrylonitrile. Also, the K011 stream contains about 10 percent dissolved sulfates. Waste characterization data for K011 are presented in Table 2-2.

The K013 waste stream typically contains about 26 to 60 ppm of cyanide, less than 35 ppm of acetonitrile, less than 10 ppm of acrylonitrile, less than 120 ppm of acrylamide, and less than 1 ppm of acrolein. This waste stream is generally 99 percent water. Waste characterization data for K013 are presented in Table 2-3.

Primary pollutants in the K014 waste stream are acetonitrile and cyanide. Generally, the K014 waste stream contains 1,000 to 60,000 ppm of acetonitrile and 130 to 10,000 ppm of ethyl cyanide and is 83 to 99 percent water. Waste characterization data for K014 are presented in Table 2-4.

It is current practice to mix the waste streams in settling ponds/tanks where the suspended solids (nonwastewater) are separated as a sludge and the liquid (wastewater) is injected into a deep well. Waste characterization data for mixed K011/K013/K014 wastewaters and mixed K011/K013/K014 nonwastewaters are presented in Table 2-5.

2.3 Determination of Waste Treatability Group

In cases where EPA believes that constituents present in different listed wastes can be treated to similar concentrations by using the same technologies, the Agency may combine the listed wastes into one separate treatability group.

The Agency has determined that the acrylonitrile waste codes (K011, K013, and K014) represent a separate waste treatability group. This determination was made because these wastes originate from the same industry and similar processes and have similar chemical characteristics. Although concentrations of specific constituents will vary from one listed waste to another, all of the wastes contain similar constituents and are expected to be treatable to similar levels using the same technologies. Furthermore, in a typical production facility, the acrylonitrile waste streams (K011, K013, and possibly K014) are commingled prior to their ultimate disposal. The mixed waste is sent to settling ponds/tanks, where the suspended solids are removed as an underflow sludge and the liquid is disposed of in deep wells.

The Agency is aware that all acrylonitrile production facilities generate K011 and K013 waste streams and only those facilities that purify the crude acetonitrile generate the K014 waste stream. However, the Agency believes the K011/K013/K014 waste matrix to be more difficult to treat than the K011/K013 matrix. This assumption is based on the characterization data for the individual wastes showing K014 to be concentrated with BDAT constituents. Consequently, EPA has examined the characteristics of the K011/K013/K014 mixed wastes, applicable treatment technologies, and treatment performance levels attainable in order to support a single regulatory approach for the three wastes as a K011/K013/K014 nonwastewater mixture and a K011/K013/K014 wastewater mixture.

Table 2-1 Major Constituent Analysis of Untreated K011, K013, and K014 Listed Wastes

Major constituents	Concentration (wt %)				
	K011	K013	K014	Mixed K011/K013/K014 wastewater	Mixed K011/K013/K014 nonwastewater
Ammonium sulfate	10	-	-	1.0	-
BDAT list volatile constituents (including acrolein, acetonitrile, acrylonitrile, benzene, ethyl cyanide)	0.5	<0.1	6	0.9	4
Cyanide	0.5	<0.1	<1	0.1	16
Inert solids (including silicon, molybdenum, iron, aluminum oxides)	4	0.8	-	<1.0	50
Water	85	99	93	97	30

- = No analysis performed.

Table 2-2 BDAT Constituent Composition and Other Data for K011

Analysis	Untreated K011 waste characterization (mg/kg) (a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
BDAT List Volatiles:										
Acrolein	200	-	-	-	-	30.1	-	60-120	-	-
Acetonitrile	3,000	-	-	-	3,000	2,300	-	40-2,800	1,100	-
Acrylamide	1,000	-	-	-	-	2,040	-	-	-	-
Acrylonitrile	>500	-	-	<0.2	<500	5,420	-	100-2,500	8,000	-
Benzene	-	-	-	-	-		-	-	100	-
Ethyl cyanide	-	-	-	-	-		-	-	47	-
Pyridine	-	-	-	-	-		-	-	300	-
BDAT List Semivolatiles:										
Phenol	-	-	-	<0.03	-	-	-	-	0.13	-
BDAT List Metals:										
Antimony	-	-	-	-	-	-	-	-	0.20	-
Arsenic	-	-	-	-	-	-	-	-	0.21	-
Barium	-	-	-	-	-	-	-	-	0.004	-
Nickel	-	-	-	-	-	-	-	-	0.59	-
Lead	-	-	-	-	-	-	-	-	0.04	-
Zinc	-	-	-	-	-	-	-	-	0.02	
Other BDAT List Inorganics:										
Cyanide	-	270	700	100	-	1,240	-	-	3,700	-
Cyanide (as hydrogen cyanide)	4,000	-	-	<0.2	7,000	-	-	-	-	-
Fluoride	-	-	-	-	-	-	-	-	47	-
Others:										
Acetaldehyde	1,000	-	-	-	-	-	-	-	-	-
Acetic acid	2,000	-	-	-	-	-	-	-	-	-
Acrylic acid	300	-	-	-	-	-	-	-	-	-
Acrylonitrile polymer	-	-	-	-	-	-	-	-	-	-
Ammonia	16,500	19,000	24,000	9,300	15,000	-	-	-	-	
Ammonia sulfate	-	-	-	-	-	-	100,000 -			100,000 120,000
Ash content	-	1,000	-	-	-	-	-	-	-	

Table 2-2 (continued)

Analysis	Untreated K011 waste characterization (mg/kg)									
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Others (continued):										
BOD	-	-	-	-	-	46,300	-	-	-	-
Boron	-	-	-	0.4	-	-	-	-	-	-
Btu content (Btu/lb)	-	-	-	-	-	-	-	-	524	-
COD	-	-	-	-	-	65,500	-	-	-	-
Fumaronitrile	500	-	-	-	-	-	-	-	-	-
Hydrogen sulfide	-	-	-	-	-	-	-	-	6	-
Nitriles	2,800	-	-	-	-	-	-	-	-	-
Nitrogen (as amide)	3,100	-	-	-	-	-	-	-	-	-
Nitrogen (as ammonia)	13,700	-	-	-	-	-	-	-	-	-
Nitrogen (as nitrate)	61	-	-	-	-	-	-	-	-	-
Nitrogen (as nitrile)	4,200	-	-	-	-	-	-	-	-	-
Nitrogen (as nitrite)	540	-	-	-	-	-	-	-	-	-
pH	4.9-5.0	-	-	-	-	-	-	-	-	-
Phosphorous	-	-	-	0.4	-	-	-	-	-	-
Polymeric material	60,000	-	-	-	-	-	-	-	-	-
Sulfates	32,000	74,000	86,000	90,000	32,000	-	-	-	-	-
Sulfur	-	-	-	-	-	-	-	-	1.4	-
Suspended solids	-	-	-	-	40,000	-	-	-	-	-
TOC	-	-	-	-	-	26,000	-	-	-	-
Water	-	-	-	-	-	-	900,000	-	900,000	-

- = No analysis performed.

(a) Reference: USEPA 1986a.

(b) Reference: USEPA 1986a.

(c) Reference: USEPA 1986a.

(d) Reference: USEPA 1986a.

(e) Reference: USEPA 1980.

(f) Reference: Memorandum from Samuel L. Hayes, EER Laboratory Manager, to Lisa Brown, HWERL Project Officer, on November 25, 1987, concerning sample results.

(g) Reference: Memorandum from Radha Krishman, PEI, to Ron Turner, EPA-ORD, on October 23, 1987, concerning telephone conversation with Steve Lang, Environmental Superintendent for the Sohio Lima Plant.

(h) Reference: Memorandum from Duane Parker, Dyanamac, to Yvonne Garbe, EPA-OSW, on January 2, 1987.

(i) Reference: USEPA 1988a.

(j) Reference: Memorandum from Radha Krishman, PEI, to Ron Turner, EPA-ORD, on December 9, 1987, concerning site visit to Schio Chemical.

2284g

Table 2-3 BDAT Constituent Composition and Other Data for K013

Analysis	Untreated K013 waste characterization (mg/kg) (a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
BDAT List Volatiles:								
Acetone	-	-	-	-	-	-	-	0.45
Acetonitrile	35	-	-	-	35	26.5	-	6.8
Acrolein	-	-	-	0.8	-	0.34	-	-
Acrylamide	-	-	-	-	-	120	-	-
Acrylonitrile	<10	-	-	2.5	<10	1.61	-	2.1
BDAT List Semivolatiles:								
Phenol	-	-	-	<0.01	-	-	-	-
BDAT List Metals:								
Arsenic	-	-	-	-	-	-	-	0.019
Barium	-	-	-	-	-	-	-	0.030
Nickel	-	-	-	-	-	-	-	0.02
Lead	-	-	-	-	-	-	-	0.003
Zinc	-	-	-	-	-	-	-	0.02
Other BDAT List Inorganics:								
Cyanide	-	35	26	60	-	34	-	31
Cyanide (as hydrogen cyanide)	225	-	-	-	225	-	-	-
Others:								
Acetic acid	120	-	-	-	-	-	-	-
Ammonia	220	143	500	300	-	-	-	-
Ash	-	4,000	-	-	-	-	-	-
BOD	-	-	-	-	-	46,300	-	-
Boron	-	-	-	0.2	-	-	-	-
Btu content (Btu/lb)	-	-	-	-	-	-	-	103
COD	-	-	-	-	-	15,800	-	-
Nitriles	6,700	-	-	-	-	-	-	-
pH	-	6.7	-	5.2	-	-	-	-
Phosphorous	-	-	-	19	-	-	-	-
Sulfates	500	153	-	36	-	-	-	-
TOC	-	-	-	-	-	4,810	1,000	4,800
Water	-	-	-	--	-	-	990,000	1,000,000

Table 2-3 (continued)

- = No analysis performed.

(a) Reference: USEPA 1986a.

(b) Reference: USEPA 1986a.

(c) Reference: USEPA 1986a.

(d) Reference: USEPA 1986a.

(e) Reference: USEPA 1980.

(f) Reference: Memorandum from Samuel L. Hayes, EER Laboratory Manager, to Lisa Brown, HWERL Project Officer, on November 25, 1987, concerning sample results.

(g) Reference: Memorandum from Radha Krishnan, PEI, to Ron Turner, EPA-ORD, on October 23, 1987, concerning telephone conversation with Steve Lang, Environmental Superintendent for the Sohio Lima Plant.

(h) Reference: USEPA 1988b.

Table 2-4 BDAT Constituent Composition and Other Data for K014

Analysis	Untreated K014 waste characterization (mg/kg)				
	(a)	(b)	(c)	(d)	(e)
BDAT List Volatiles:					
Acetone	-	-	-	-	4.3
Acetonitrile	1,000-2,000	-	22,000	60,000	3,000
Dichlorodifluoromethane	-	-	-	-	9.1
Ethyl cyanide	-	-	-	10,000	130
Pyridine	-	-	-	1,700	99
BDAT List Semivolatiles:					
2-Picoline	-	-	-	120	-
BDAT List Metals:					
Antimony	-	-	<0.85	0.05	<0.034
Barium	-	-	<0.05	0.01	0.009
Cadmium	-	-	<0.10	0.006	0.02
Chromium	-	-	<0.18	0.03	0.01
Copper	-	-	<0.15	0.05	0.03
Nickel	-	-	<0.38	0.04	0.02
Lead	-	-	<0.05	0.011	0.04
Zinc	-	-	0.07	0.03	0.04
Other BDAT List Inorganics:					
Cyanide	5,000	-	4.3	300	4,500
Others:					
Btu content (Btu/lb)	-	-	1,589	718	435
pH	2.0-2.5	-	-	-	-
TOC	-	1,000	-	-	-
Water	-	990,000	834,000	932,000	960,000

- = No analysis performed.

(a) Bottoms from the acetonitrile purification column in the production of acrylonitrile (Reference: USEPA 1985).

(b) Reference: Memorandum from Radha Krishnan, PEI, to Ron Turner EPA ORD, on October 23, 1987, concerning Telephone conversation with Steve Lang, Environmental Superintendent for the Sohio Lima Plant.

(c) Reference: USEPA 1988b.

(d) Reference: USEPA 1988b.

(e) Reference: USEPA 1988b.

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Table 2-5 BDAT Constituent Composition and Other Data for K011/K013/K014 Mixed Wastes

Analysis	Untreated mixed K011/K013/K014 waste characterization (mg/kg)				
	(a)	(b)	(c)	(d)	(e)
BDAT List Volatiles:					
Acetonitrile	0.68-2.7	177	500-50,000	420-490	575
Acetone	0.04-0.095	-	-	-	24.4
Acrylamide	2.4-2.9	-	-	-	270
Acrylonitrile	0.41-0.95	217	-	<5-65	-
Benzene	48-61	-	-	-	-
Chloroform	0.030-0.042	-	-	-	-
Methylene chloride	0.023-0.042	-	-	-	-
1,1,1-Trichloroethane	0.026-0.045	-	-	-	-
Trichloroethene	0.014-0.019	-	-	-	-
Styrene	14-19	-	-	-	-
BDAT List Semivolatiles:					
Phenol	-	4.2	-	-	-
BDAT List Metals:					
Arsenic	2.7-6.2	0.02	-	-	<0.05
Barium	82-200	-	-	-	15.4
Cadmium	2.0-2.9	-	-	-	<0.04
Chromium	95-200	0.17	-	-	0.38
Lead	35-41	-	-	-	0.012
Nickel	280-470	3.2	-	-	1.08
Zinc	140-210	0.28	-	-	1.8
Other BDAT List Inorganics:					
Cyanide	5,000-5,200	391	500-50,000	240-350	1,277
Cyanide (as hydrogen cyanide)	-	-	20,000-250,000	-	-
Fluoride	56-73	-	-	-	-

Table 2-5 (continued)

Analysis	Untreated mixed K011/K013/K014 waste characterization (mg/kg) (a)	(b)	(c)	(d)	(e)
Other:					
Acrylonitrile polymer	-	-	20,000-250,000	-	-
Aluminum	500-1,100	-	-	-	-
Aluminum oxide	-	-	20,000-500,000	-	-
Ammonia	-	4,000	-	-	-
BOD (biological oxygen demand)	-	-	-	-	7,207
COD (chemical oxygen demand)	-	-	-	6,440-26,100	37,900
Copper	12-22	-	-	-	0.20
Iron	2,000-4,000	5.9	20,000-500,000	-	-
Molybdenum	8,300-17,000	40.1	20,000-500,000	-	73.6
pH	-	-	-	-	8.1
Phosphorous	-	2.4	-	-	-
Silicon	45-200	-	-	-	-
Sulfate	33,000-36,000	12,000	20,000-500,000	29,000-45,000	-
Total solids	-	-	100,000-400,000	-	91,000
TDS (total dissolved solids)	-	-	-	53,000-75,000	-
TOC (% carbon)	17-31	-	-	-	-
Water (%)	-	97	10-30	-	-

- = No analysis performed.

(a) Nonwastewater from the bottom of a surface impoundment containing K011, K013, and K014. (Reference: USEPA 1988a.)

(b) Combined K011, K013, and K014 wastewater. Aqueous waste includes plant washdown water, transport vehicle flush water, and rainwater runoff from the manufacturing unit. (Reference: USEPA 1985.)

(c) Combined K011, K013, and K014 nonwastewater. (Reference: USEPA 1985.)

(d) Combined K011, K013, and K014 wastewaters. (Reference: Memorandum to Ronald Turner, EPA-OSW, from Radha Krishnan, PEI, on February 1, 1988.)

(e) Combined K011, K013, and K014 wastewaters. (Reference: Memorandum to James Berlow, EPA-OSW, from Ronald Turner, EPA-ORD, on June 21, 1988, concerning the results of wet air oxidation bench-scale tests of K011, K013, and K014 mixed sludge.)

3. APPLICABLE AND DEMONSTRATED TECHNOLOGIES

Section 2 established one treatability group for the management of K011, K013, and K014 wastes. This section identifies the treatment technologies that are applicable to this group and determines which, if any, of the applicable technologies can be considered demonstrated for the purposes of establishing BDAT.

To be applicable, a technology must be theoretically capable of treating the waste in question or of treating a waste that is similar in terms of the parameters that affect treatment selection. (For detailed descriptions of the technologies that are applicable for these wastes, or for wastes judged to be similar, see EPA's Treatment Technology Background Document (USEPA 1988f)). To be demonstrated, the technology must be employed in full-scale operation for the treatment of the waste in question or a similar waste. Technologies that are available only at pilot- and bench-scale operations are not considered in identifying demonstrated technologies.

3.1 Applicable Treatment Technologies

Initial data gathering on the treatment of K011, K013, and K014 wastes included phone contacts with industry, review of the technical literature, and contacts with the EPA Office of Research and Development.

Characterization data presented in Section 2 show that the K011, K013, and K014 listed wastes contain BDAT list organics, BDAT list metals, and cyanide. The K011 and K014 listed wastes are nonwastewaters and K013 is a wastewater; however, most generators of the acrylonitrile wastes mix them together in a settling pond/tank, which generally results in a K011/K013/K014 wastewater and nonwastewater. The treatment technologies considered applicable for both the nonwastewater and wastewater forms are those that destroy or recover the various BDAT list organic compounds and destroy cyanide. Stabilization treatment technologies are considered applicable for BDAT list metals present in the nonwastewaters, while technologies that remove the BDAT list metals are considered applicable for the wastewaters.

The applicable technologies that the Agency has identified for treatment of BDAT list organics and cyanide present in K011/K013/K014 nonwastewater are rotary kiln incineration and wet air oxidation.

Incineration is a technology that destroys the cyanide and organic components in the waste. Treatment of K011/K013/K014 nonwastewater using incineration generates an ash residual that may also require metals treatment. For the BDAT list metals present in the ash residuals, the applicable treatment technology is stabilization. Stabilization is a technology that immobilizes the metal constituents to minimize leaching.

Wet air oxidation is a technology used to treat aqueous wastes that contain certain BDAT list organics and oxidizable inorganics such as cyanide. Wet air oxidation reduces the organic concentrations in the treatment residuals generated when using wet air oxidation (i.e., wastewater effluent and reactor still bottoms). Nevertheless, these residues may still contain quantities of BDAT list organic and cyanide concentrations that may require further treatment prior to disposal.

The applicable technologies that the Agency has identified for treatment of BDAT list organics and cyanide present in K011/K013/K014 wastewaters are (1) critical fluid extraction followed by cyanide treatment of the aqueous phase, (2) wet air oxidation, and (3) wet air oxidation followed by biological treatment.

Critical fluid extraction is a technology that takes advantage of the enhanced solubilities of various organic compounds in hydrocarbon and other solvents under pressure. When using critical fluid extraction for treatment of the acrylonitrile wastes, an aqueous phase (raffinate) and a solvent phase (extract) will be generated. The wastewater phase may require cyanide treatment, and the nonwastewater phase may be recycled or incinerated. For a complete discussion of all applicable and demonstrated treatment technologies for wastewaters containing cyanides, see EPA's Best Demonstrated Available Treatment (BDAT) Background Document for Cyanide Wastes (USEPA 1988d).

Wet air oxidation is a treatment technology that oxidizes hazardous organic compounds at elevated temperatures and pressures into carbon dioxide, water vapor, and halogen acids (in the case of halogenated wastes). It is important to point out that sometimes wet air oxidation may not achieve complete oxidation of the organic constituents, and additional treatment of the wastewater effluent by aerobic biological treatment may be necessary.

Biological treatment is a technology that uses living microorganisms to decompose organic constituents into carbon dioxide, water, and nonhazardous organic compounds.

For BDAT list metals present in the K011/K013/K014 wastewaters after organic and cyanide treatment, the Agency has determined that the applicable treatment technologies are chemical precipitation and removal of precipitated solids using settling and/or sludge filtration. Polishing filtration may also be applicable if the solids formed are difficult to settle or remove by the sludge filtration process. Chemical precipitation removes dissolved metals from solution, and settling/sludge filtration removes suspended solids.

3.2 Demonstrated Treatment Technologies

The Agency believes that incineration is demonstrated to treat the BDAT list organics and cyanide present in the K011/K013/K014 nonwastewaters. The Agency has identified one facility performing pilot-scale incineration tests on the K011/K013 nonwastewaters. Incineration of the K011/K013/K014 nonwastewaters has also been tested at an EPA test facility. Furthermore, incineration is a proven full-scale technology for destroying organics and cyanides in numerous hazardous waste streams. Hence, the Agency believes that incineration is demonstrated for K011/K013/K014 nonwastewaters.

The Agency has not identified facilities using stabilization on the ash that would be generated during the incineration of mixed K011/K013/K014 nonwastewaters. However, stabilization is a proven full-scale technology for immobilizing metals in numerous incinerator ashes and other nonwastewater streams. Thus, the Agency considers stabilization to be demonstrated for K011/K013/K014 nonwastewaters.

Wet air oxidation is demonstrated to treat K011/K013/K014 nonwastewaters. EPA has identified one facility that is currently performing pilot-scale tests on the K011/K013/K014 nonwastewaters. In addition, wet air oxidation is a proven full-scale technology for treating organics and cyanides in numerous hazardous wastes. Thus, the Agency considers wet air oxidation to be demonstrated for K011/K013/K014 nonwastewaters.

The Agency does not believe that critical fluids extraction is demonstrated to treat K011/K013/K014 mixed wastewaters. The Agency has received bench-scale data for treatment of a simulated acrylonitrile waste, using near-critical fluids extraction with carbon dioxide as the extracting medium. The data indicate that critical fluids extraction is an applicable technology for removal of acrylonitrile and acetonitrile. However, the Agency believes the simulated waste was easier to treat than actual acrylonitrile wastes for the following reasons. The simulated waste did not contain ammonium sulfate (a constituent generally present in the waste). Moreover, the Agency has data indicating that when carbon dioxide is used as the extraction fluid, the presence of a significant amount of alkalinity will interfere with the process because carbon dioxide will react to form carbonates and bicarbonates. This will result in excessive carbon dioxide consumption. In addition, since the simulated waste contained only acrylonitrile and acetonitrile, the extraction of the other organic constituents commonly found in K011/K013/K014 wastewaters is unknown. Also, the simulated waste used for testing did not contain hydrogen cyanide (another constituent generally present in the acrylonitrile wastes); hence, it is not known how this treatment affects cyanide concentrations or is affected by the presence of cyanides. In conclusion, EPA will continue to investigate critical fluids extraction for treatment of the K011/K013/K014 wastewater, but will not consider it as demonstrated for the purposes of this document.

EPA believes that wet air oxidation is demonstrated to treat the cyanide and organics present in the mixed K011/K013/K014 wastewaters. The Agency has identified at least one facility using wet air oxidation for treatment of K011/K013/K014 wastewaters. The Agency has not identified any facilities using biological treatment of K011/K013/K014 wastewaters. Biological treatment, however, is demonstrated on an acrylonitrile-containing wastewater that has similar parameters affecting treatment selection, and thus the Agency considers biological treatment to be demonstrated for K011/K013/K014 wastewaters. The similarities between the K011/K013/K014 wastewater and the acrylonitrile-containing wastewater are discussed in Section 4.

The Agency has not identified any facilities using chemical precipitation followed by settling or sludge filtration on the K011/K013/K014 wastewaters. However, this treatment system is demonstrated on a BDAT list metal-containing wastewater that has similar parameters affecting treatment selection, and thus the Agency considers the treatment to be demonstrated for the K011/K013/K014 wastewaters. The similarities between the K011/K013/K014 wastewater and the BDAT list metal-containing wastewater are discussed in Section 4.

Detailed discussions of incineration, wet air oxidation, critical fluids extraction, biological treatment, chemical precipitation, sludge filtration, and stabilization, are presented in Appendix B through Appendix H.

4. TREATMENT PERFORMANCE DATA BASE

This section presents the data available to EPA on the performance of demonstrated technologies in treating the K011, K013, and K014 listed wastes. These data are used elsewhere in this document for determining which technologies represent BDAT (Section 5), for selecting constituents to be regulated (Section 6), and for developing treatment standards (Section 7). In addition to full-scale demonstration data, the data used to develop treatment standards may include data developed at research facilities or obtained through other applications at less than full-scale operation, as long as the technology is demonstrated in full-scale operation for a similar waste or wastes as defined in Section 3.

Performance data, to the extent that they are available to EPA, include the untreated and treated waste concentrations for a given constituent, values of operating parameters that were measured at the time the waste was being treated, values of relevant design parameters for the treatment technology, and data on waste characteristics that affect performance of the treatment technology.

Where data are not available on the treatment of the specific wastes of concern, the Agency may elect to transfer data on the treatment of a similar waste or wastes, using a demonstrated technology. To transfer data from another waste category, EPA must find that the wastes covered by this background document are no more difficult to treat (based on the waste characteristics that affect performance of the demonstrated treatment technology) than the treated wastes from which treatment performance levels are being transferred.

4.1 Nonwastewaters

4.1.1 Organics and Cyanide Treatment Data

EPA tested incineration to demonstrate the actual performance achievable by this technology for treatment of the BDAT list organics and cyanide present in the K011/K013/K014 nonwastewaters. Since EPA is not aware of any generator or treatment, storage, and disposal (TSD) facility currently using full-scale incineration for treatment of K011, K013, and K014 listed wastes, the K011/K013/K014 nonwastewaters were collected from a generator and incinerated at a commercial facility, John Zink Company in Tulsa, Oklahoma.

The Agency has received incineration performance data from an industrial source testing incineration as a treatment for K011/K013 nonwastewaters; however, no BDAT list constituent concentrations for the treatment residuals (i.e., scrubber water, ash) were reported. These data have been requested and may be presented as part of the final background document for the acrylonitrile wastes.

EPA has five untreated and treated data sets for K011/K013/K014 nonwastewaters using rotary kiln incineration at the commercial facility. These data are shown in Table 4-1 at the end of this section. Each of the five data sets shows significant treatment for two of the BDAT list organics (i.e., benzene, styrene) and cyanide detected in the untreated K011/K013/K014 nonwastewaters. (For a discussion on significant treatment, see Section 5.) The treated data represent total waste concentration found in the scrubber water and ash residuals.

Operating data and design data collected during the test are also shown in Table 4-1. These data indicate that the system was operated within the design specifications.

The Agency has received wet air oxidation performance data from an industrial source. However, these data and all treatment process information have been classified as confidential business information in Table 4-6 and cannot be presented in the K011/K013/K014 background document. These data are located in the RCRA CBI docket.

4.1.2 Metals Treatment Data

For the metals present in the ash generated from incineration of K011/K013/K014 nonwastewater, the Agency tested stabilization at the U.S. Army Corps of Engineers Waterways Experiment Station (WES) to demonstrate the actual performance achievable by this technology. EPA has nine untreated and treated data sets for K011/K013/K014 ash residual using stabilization with three different binding agents. Each of the data sets provides performance data for the BDAT list metals detected in the untreated K011/K013/K014 ash residual. These data, presented in Table 4-2, reflect total waste and TCLP leachate concentrations for BDAT list metals in the untreated waste and TCLP leachate concentrations for the BDAT list metals in the treated waste. Because the Agency has not reviewed the design and operating data at this time, it cannot be determined whether the system was operating within the design specifications.

In addition to the WES stabilization data, data are available for stabilization of a metal-bearing nonwastewater (F006). These data are presented in EPA's Best Demonstrated Available Technology (BDAT) Background Document for F006 (USEPA 1988i). The Agency believes these data represent a level of performance for metals treatment that can be achieved for K011/K013/K014 nonwastewaters by using stabilization.

EPA reviewed the characterization data for the untreated ash residual presented in Table 4-2, as well as data on parameters that would affect the performance of the stabilization system. The only data available for evaluation were type and concentration of metals.

The concentrations of untreated BDAT list metals in the tested F006 nonwastewaters are greater than the BDAT list metal concentrations in the K011/K013/K014 nonwastewaters. Specifically, the principal BDAT list metals in the K011/K013/K014 nonwastewaters are present at total concentrations less than 990 ppm for chromium, less than 1,400 ppm for zinc, and less than 2,700 ppm for nickel. In the F006 nonwastewaters, the total concentrations for chromium range up to 42,900 ppm, for zinc range from up to 90,200 ppm, and for nickel range up to 23,700 ppm. Additionally, the untreated F006 waste has a high oil and grease content. In conclusion, these data show that the F006 nonwastewaters would be more difficult to stabilize than the K011/K013/K014 nonwastewaters.

4.2 Wastewaters

4.2.1 Organics and Cyanide Treatment Data

EPA performed wet air oxidation tests on the K011/K013/K014 wastewaters to determine whether wet air oxidation is an applicable technology for the treatment of the organics and cyanide present in the K011/K013/K014 wastewaters. The data from these tests are shown in

Table 4-3. Three separate treatment tests were performed at different temperatures to determine the optimum operating temperature for treatment of the K011/K013/K014 wastewaters. For each test only one set of untreated waste and treated waste samples was collected. These data show treatment performance for three BDAT organics and cyanide.

The Agency has additional cyanide treatment performance data using wet air oxidation of a cyanide-containing waste (F007). The Agency believes this waste to be more difficult to treat than the K011/K013/K014 wastewaters because of the higher cyanide concentrations. No other waste characteristics that affect performance of the wet air oxidation treatment system were available for comparison. The available data are shown in Table 4-4. These data consist of six untreated and treated waste sample sets. Each of the six untreated samples has three corresponding treated streams. The three treated streams are the wastewater effluent, solids scraped off the reactor wall, and solids remaining in the bottom of the reactor.

The Agency believes that when using wet air oxidation to treat K011/K013/K014 wastewaters, the organic concentrations are reduced to levels that are treatable by biological treatment. The Agency does not have biological treatment performance data for the wastewater generated from treatment of K011/K013/K014 wastewaters using wet air oxidation. However, EPA does have data for biological treatment of a similar waste that the Agency believes represent a level of treatment performance that can be achieved for the K011/K013/K014 wet air oxidation effluent wastewater. The Agency believes this waste to be more difficult to treat than the K011/K013/K014 wet air oxidation effluent wastewater because of the higher acrylonitrile concentrations. Specifically, the concentration of acrylonitrile in the K011/K013/K014 wet air oxidation effluent wastewater is 90 ppm and the concentration of the acrylonitrile in the similar wastewater ranges from 93 to 415 ppm. These data are presented in Table 4-5 and consist of 13 untreated and treated sample sets.

4.2.2 Metals Treatment Data

The Agency does not have performance data on treatment of the BDAT metals in the K011/K013/K014 wastewaters. However, data are available from EPA's testing of a metal-bearing wastewater (K062). These data are presented in EPA's Best Demonstrated Available Technology (BDAT) Background Document for K062 (USEPA 1988e). The Agency believes these data represent a level of performance for metals treatment that can be achieved for K011/K013/K014 wastewaters by using lime precipitation followed by dewatering.

EPA reviewed the available characterization data for K011/K013/K014 mixed wastewaters presented in Table 2-5, as well as data on parameters that would affect the performance of the EPA-tested metal treatment system (i.e., oil and grease content, complex metal concentration, and type and concentration of metals). The only data available for evaluation were type and concentration of metals.

The concentrations of untreated BDAT list metals in the tested K062 wastewaters are greater than the BDAT list metal concentrations in the K011/K013/K014 wastewaters. Specifically, the principal BDAT list metals in the K011/K013/K014 wastewaters are present at concentrations less than

15.4 mg/l for barium, less than 3.2 mg/l for nickel, less than 0.38 mg/l for chromium, and less than 1.8 mg/l for zinc. In the K062 wastewaters, the concentrations for barium are less than 10 mg/l, the concentrations for nickel range from 4 to 100,310 mg/l, the concentrations for chromium range from 6 to 7,000 mg/l, and the concentrations for zinc range from 0.4 to 9 mg/l. In conclusion, these data show that the K011/K013/K014 wastewaters would be no more difficult to treat than the K062 wastewaters.

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Table 4-1 Performance Data Collected by EPA for Incineration of K011/K013/K014 Nonwastewaters

Analytical data

	BDAT list constituent concentrations								
	Sample Set No. 1			Sample Set No. 2			Sample Set No. 3		
BDAT list constituents	Mixed K011/K013/K014 nonwastewaters (mg/kg)	Scrubber water (mg/l)	Ash (mg/kg)	Mixed K011/K013/K014 nonwastewaters (mg/kg)	Scrubber water (mg/l)	Ash (mg/kg)	Mixed K011/K013/K014 nonwastewaters (mg/kg)	Scrubber water (mg/l)	Ash (mg/kg)
Volatiles									
Acetonitrile	0.870	<0.5	<0.5	0.68	<0.5	<0.5	1.2	-	-
Acrylonitrile	0.410	<0.5	<0.5	0.52	<0.5	<0.5	0.54	-	-
Acrylamide	2.8	<0.25	<6.5	2.4	<0.25	<6.5	2.6	-	-
Acetone	<0.04	<0.25	<0.25	<0.04	<0.25	<0.25	0.095	-	-
Benzene	57	<0.01	<0.01	61	<0.01	<0.01	48	-	-
Chloroform	0.032	<0.01	<0.01	0.39	<0.01	<0.01	0.030	-	-
Methylene chloride	0.034	<0.25	<0.25	0.023	<0.25	<0.25	0.24	-	-
Styrene	16	<0.01	<0.01	19	<0.01	<0.01	15	-	-
1,1,1-Trichloroethane	0.045	<0.01	<0.01	0.026	<0.01	<0.01	0.029	-	-
Trichloroethene	0.016	<0.01	<0.01	0.019	<0.01	<0.01	0.014	-	-
Inorganics									
Cyanide	1200	<0.1	10	1400	<0.1	5.8	2000	-	-

Design and Operating Data

Kiln	Design value	Sample Set No. 1	Sample Set No. 2	Sample Set No. 3
Temperature (°F)	1600-2000	1728-1840	1741-1815	1796-1834
Revolutions per minute (rpm)	0.25	0.25	0.25	0.25
Afterburner				
Temperature (°F)	2000	1984-2004	1972-2005	2002-2012
Excess oxygen (%)	no value reported	4.2-7.0	3.7	3.5-4.0
Carbon monoxide (ppm)	no value reported	3.5-4.6	<10	<10

Table 4-1 (Continued)

Analytical data	BDAI list constituent concentrations								
	Sample Set No. 4			Sample Set No. 5			Sample Set No. 6		
BDAT list constituents	Mixed K011/K013/K014 nonwastewaters (mg/kg)	Scrubber water (mg/l)	Ash (mg/kg)	Mixed K011/K013/K014 nonwastewaters (mg/kg)	Scrubber water (mg/l)	Ash (mg/kg)	Mixed K011/K013/K014 nonwastewaters (mg/kg)	Scrubber water (mg/l)	Ash (mg/kg)
Volatiles									
Acetonitrile	1.9	<0.5	<0.5	2.7	<0.5	<0.5	-	-	-
Acrylonitrile	0.63	<0.5	<0.5	0.95	<0.5	<0.5	-	-	-
Acrylamide	2.7	<0.25	<6.5	2.9	<0.25	<6.5	-	-	-
Acetone	<0.04	<0.25	<0.25	0.081	<0.25	<0.25	-	-	-
Benzene	59	<0.01	<0.01	55	<0.01	<0.01	-	-	-
Chloroform	0.034	<0.01	<0.01	0.042	<0.01	<0.01	-	-	-
Methylene chloride	0.041	<0.25	<0.25	0.21	<0.25	<0.25	-	-	-
Styrene	16	<0.01	<0.01	18	<0.01	<0.01	-	-	-
1,1,1-Trichloroethane	0.02	<0.01	<0.01	0.032	<0.01	<0.01	-	-	-
Trichloroethene	0.017	<0.01	<0.01	0.018	<0.01	<0.01	-	-	-
Inorganics									
Cyanide	1300	<0.1	22	1500	<0.1	4.8	-	-	9.0

Design and Operating Data

Kiln	Design value	Sample Set No. 4	Sample Set No. 5	Sample Set No. 6
Temperature (°F)	1600-2000	1768-1831	1761-1874	1780-1822
Revolutions per minute (rpm)	0.25	0.25	0.25	0.25
Afterburner				
Temperature (°F)	2200	2002-2014	2009-2037	1991-2004
Excess oxygen (%)	no value reported	4.3-5.1	4.4-5.6	3.2-5.2
Carbon monoxide (ppm)	no value reported	<10	<10	<10

Table 4-1 (Continued)

Analytical data	BDAT list constituent concentrations		
	Sample Set No. 7		
BDAT list constituents	Mixed K011/K013/K014 nonwastewaters (mg/kg)	Scrubber water (mg/l)	Ash (mg/kg)
Volatiles			
Acetonitrile	-	-	-
Acrylonitrile	-	-	-
Acrylamide	-	-	-
Acetone	-	-	-
Benzene	-	-	-
Chloroform	-	-	-
Methylene chloride	-	-	-
Styrene	-	-	-
1,1,1-Trichloroethane	-	-	-
Trichloroethene	-	-	-
Inorganics			
Cyanide	-	-	12

Design and Operating Data		
Kiln	**Design value**	**Sample Set No. 7**
Temperature (°F)	1600-2000	1765-1834
Revolutions per minute (rpm)	0.25	0.25
Afterburner		
Temperature (°F)	2200	1992-2012
Excess oxygen (%)	no value reported	3.6-4.8
Carbon monoxide (ppm)	no value reported	<10

- = No analysis performed.

Table 4-2 Stabilization Testing - EPA-Collected Data

BDAT list Constituent	Untreated waste Total (ppm)	Untreated waste TCLP (mg/l)	Test No. 1 - Binder: Cement Treated waste - TCLP (mg/l) Run #1	Run #2	Run #3	Test No. 2 - Binder: Kiln Dust Treated waste - TCLP (mg/l) Run #1	Run #2	Run #3	Test No. 3 - Binder: Lime/Fly Ash Treated waste TCLP (mg/l) Run #1	Run #2	Run #3
Arsenic	19 - 140	0.014-0.23	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005
Antimony	26 - 120	NA	1.30	1.23	1.20	1.40	1.30	1.27	1.32	1.30	1.24
Barium	200 - 770	0.28-0.84	.238	.249	.251	.213	.193	.212	.217	.193	.213
Beryllium	<0.5	NA	<.010	<.010	<.010	<.010	<.010	<.010	<.010	<.010	<.010
Cadmium	2.0	<0.11	<.010	<.010	<.010	<.010	<.010	<.010	<.010	<.010	<.010
Chromium	130 - 990	0.20-6.7	.018	<.010	<.010	.018	<.010	.018	.010	<.010	<.010
Hexavalent chromium	NA	NA	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Copper	76 - 140	0.062-0.80	.063	.090	.075	.094	.087	.076	.042	.043	.040
Lead	39 - 130	0.018-0.070	<.010	<.010	<.010	<.010	<.010	<.010	<.010	<.010	<.010
Mercury	<1.25	<0.0042	<.0002	.0003	<.0002	.00045	<.0002	.0003	<.0002	<.0002	<.0002
Nickel	1300 - 2700	0.11-14.0	26.0	24.4	23.9	24.2	24.8	22.5	21.8	21.6	21.8
Selenium	<1.5	0.060	<.020	<.020	<.020	<.020	<.020	<.020	<.020	<.020	<.020
Silver	<3.5-5.4	<0.0023-0.0034	<.010	<.010	<.010	<.010	<.010	<.010	<.010	<.010	<.010
Thallium	<1.0	NA	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005
Vanadium	<4.0-56	NA	.015	.016	.017	.017	.017	.018	.022	.018	.014
Zinc	120 - 1400	0.25-1.2	2.16	2.41	2.25	1.99	2.20	2.15	2.15	2.08	2.21

NA - Not analyzed.

Reference: Memorandum from Theresa Williams, WES, to Michael Arozarena, PEI on December 1, 1988, concerning the results of the stabilization of the K011/K013/K014 ash residue.

Table 4-3 Wet Air Oxidation Data Collected by EPA for Treatment of K011/K013/K014 Wastewaters

	Sample Set No. 1 concentration		Sample Set No. 2 concentration		Sample Set No. 3 concentration	
	Untreated waste (mg/l)	Treated waste (mg/l)	Untreated waste (mg/l)	Treated waste (mg/l)	Untreated waste (mg/l)	Treated waste (mg/l)
BDAT Organics						
Acetonitrile	575	690	575	560	575	90
Acrylamide	270	11	270	10	270	5
Acrylonitrile	24.4	0.470	24.4	<4.0	24.4	<4.0
BDAT List Inorganics Other Than Metals						
Cyanide (amenable)	1011	37	1011	11.4	1011	11.4
Cyanide (total)	1277	39	1277	13.6	1277	15.5

Operating Parameters	Sample Set No. 1	Sample Set No. 2	Sample Set No. 3
Reactor temperature	200°C (392°F)	240°C (464°F)	280°C (536°F)
Residence time	60 minutes	60 minutes	60 minutes
Oxygen concentration (off-gas)	11.1%	6.4%	6.7%
Reactor pressure	810 psig	810 psig	810 psig

Reference: USEPA 1988h

Table 4-4 Wet Air Oxidation Data Collected by EPA for Treatment of a Cyanide-Containing Waste (F007)

	Concentration					
	Sample Set No. 1					
	Untreated waste	Treated wastewater	Treated solids A[a]		Treated solids B[b]	
Constituent	Total (mg/l)	Total (mg/l)	Total (mg/kg)	TCLP (mg/l)	Total (mg/kg)	TCLP (mg/l)
BDAT Organics						
Methanol	570	266	<15	-	<15	-
BDAT Inorganics						
Cyanide (amenable)	32,000	0.3	<25	-	<25	-
Cyanide (total)	33,100	11.9	<25	-	<25	-
Fluoride	3.67	4.20	-	-	-	-

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Reactor temperature	440-480°F	449-487°F
Residence time	55-66 min (5.0-6.0 gal/hr)	57.1 min
Oxygen concentration (off-gas)	16-20%	17.8%
Reactor pressure	1700 psig	1690-1707 psig

[a] Reactor wall scale; one sample collected for all six sample sets.

[b] Reactor bottom solids; one sample collected for all six sample sets.

- = Not analyzed.

Table 4-4 (continued)

	Concentration					
	Sample Set No. 2					
	Untreated waste	Treated wastewater	Treated solids A[a]		Treated solids B[b]	
Constituent	Total (mg/l)	Total (mg/l)	Total (mg/kg)	TCLP (mg/l)	Total (mg/kg)	TCLP (mg/l)
BDAT Organics						
Methanol	660	<150	<15	-	<15	-
BDAT Inorganics						
Cyanide (amenable)	25,500	<0.25	<25	-	<25	-
Cyanide (total)	27,100	<0.25	<25	-	<25	-
Fluoride	7.20	4.02	-	-	-	-

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Reactor temperature	440-480°F	440-489°F
Residence time	55-66 min (5.0-6.0 gal/hr)	60.5 min
Oxygen concentration (off-gas)	16-20%	17.0%
Reactor pressure	1700 psig	1709-1725 psig

[a] Reactor wall scale; one sample collected for all six sample sets.

[b] Reactor bottom solids; one sample collected for all six sample sets.

- = Not analyzed.

Table 4-4 (continued)

	Concentration					
	Sample Set No. 3					
	Untreated waste	Treated wastewater	Treated solids A[a]		Treated solids B[b]	
Constituent	Total (mg/l)	Total (mg/l)	Total (mg/kg)	TCLP (mg/l)	Total (mg/kg)	TCLP (mg/l)
BDAT Organics						
Methanol	510	110	<15	-	<15	-
BDAT Inorganics						
Cyanide (amenable)	26,900	<0.25	<25	-	<25	-
Cyanide (total)	28,300	3.22	<25	-	<25	-
Fluoride	7.13	4.02	-	-	-	-

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Reactor temperature	440-480°F	431-488°F
Residence time	55-66 min (5.0-6.0 gal/hr)	59.2 min
Oxygen concentration (off-gas)	16-20%	17.5%
Reactor pressure	1700 psig	1701-1718 psig

[a] Reactor wall scale; one sample collected for all six sample sets.

[b] Reactor bottom solids; one sample collected for all six sample sets.

- = Not analyzed.

Table 4-4 (continued)

	Concentration					
	Sample Set No. 4					
	Untreated waste	Treated wastewater	Treated solids A[a]		Treated solids B[b]	
Constituent	Total (mg/l)	Total (mg/l)	Total (mg/kg)	TCLP (mg/l)	Total (mg/kg)	TCLP (mg/l)
BDAT Organics						
Methanol	660	64	<15	-	<15	-
BDAT Inorganics						
Cyanide (amenable)	27,400	<0.25	<25	-	<25	-
Cyanide (total)	28,800	<0.25	<25	-	<25	-
Fluoride	6.88	4.07	-	-	-	-

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Reactor temperature	440-480°F	424-493°F
Residence time	55-66 min (5.0-6.0 gal/hr)	53.3 min
Oxygen concentration (off-gas)	16-20%	16.5%
Reactor pressure	1700 psig	1675-1740 psig

[a] Reactor wall scale; one sample collected for all six sample sets.

[b] Reactor bottom solids; one sample collected for all six sample sets.

- = Not analyzed.

Table 4-4 (continued)

	Concentration					
	Sample Set No. 5					
	Untreated waste	Treated wastewater	Treated solids A[a]		Treated solids B[b]	
Constituent	Total (mg/l)	Total (mg/l)	Total (mg/kg)	TCLP (mg/l)	Total (mg/kg)	TCLP (mg/l)
BDAT Organics						
Methanol	<375	50	<15	-	<15	-
BDAT Inorganics						
Cyanide (amenable)	26,600	<0.25	<25	-	<25	-
Cyanide (total)	28,100	<0.25	<25	-	<25	-
Fluoride	6.66	4.06	-	-	-	-

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Reactor temperature	440-480°F	417-484°F
Residence time	55-66 min (5.0-6.0 gal/hr)	51.6 min
Oxygen concentration (off-gas)	16-20%	16.6%
Reactor pressure	1700 psig	1680-1694 psig

[a] Reactor wall scale; one sample collected for all six sample sets.

[b] Reactor bottom solids; one sample collected for all six sample sets.

- = Not analyzed.

Table 4-4 (continued)

Constituent	Concentration Sample Set No. 6 Untreated waste Total (mg/l)	Treated wastewater Total (mg/l)	Treated solids A[a] Total (mg/kg)	Treated solids A[a] TCLP (mg/l)	Treated solids B[b] Total (mg/kg)	Treated solids B[b] TCLP (mg/l)
BDAT Organics						
Methanol	780	36	<15	-	<15	-
BDAT Inorganics						
Cyanide (amenable)	25,000	<0.25	<25	-	<25	-
Cyanide (total)	26,000	<0.25	<25	-	<25	-
Fluoride	7.20	3.95	-	-	-	-

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Reactor temperature	440-480°F	412-494°F
Residence time	55-66 min (5.0-6.0 gal/hr)	50.8 min
Oxygen concentration (off-gas)	16-20%	17.0%
Reactor pressure	1700 psig	1674-1690 psig

[a] Reactor wall scale; one sample collected for all six sample sets.

[b] Reactor bottom solids; one sample collected for all six sample sets.

- = Not analyzed.

Reference: USEPA 1988g.

Table 4-5 Performance Data for Biological Treatment of an Acrylonitrile-Containing Wastewater

	Untreated acrylonitrile concentration (ppm)	Treated acrylonitrile concentration (ppm)
Sample Set #1	165	<0.05
Sample Set #2	195	<0.05
Sample Set #3	164	<0.05
Sample Set #4	137	<0.05
Sample Set #5	191	<0.05
Sample Set #6	234	<0.05
Sample Set #7	93	<0.05
Sample Set #8	217	<0.05
Sample Set #9	247	<0.05
Sample Set #10	415	<0.05
Sample Set #11	381	<0.05
Sample Set #12	387	<0.05
Sample Set #13	200	<0.05

Reference: USEPA 1987b.

Table 4-6 Treatment Performance Data for Wet Air Oxidation of K011/K013/K014 Nonwastewaters

	Concentration					
	Sample Set No. 1			Sample Set No. 2		
Constituent	Untreated Waste Total (mg/l)	Treated Solids Total (mg/l)	Treated Wastewater Total (mg/l)	Untreated Waste Total (mg/l)	Treated Solids Total (mg/l)	Treated Wastewater Total (mg/l)
CBI	CBI	CBI	CBI	CBI	CBI	CBI
CBI	CBI	CBI	CBI	CBI	CBI	CBI
CBI	CBI	CBI	CBI	CBI	CBI	CBI
CBI	CBI	CBI	CBI	CBI	CBI	CBI
CBI	CBI	CBI	CBI	CBI	CBI	CBI
CBI	CBI	CBI	CBI	CBI	CBI	CBI
CBI	CBI	CBI	CBI	CBI	CBI	CBI
CBI	CBI	CBI	CBI	CBI	CBI	CBI
CBI	CBI	CBI	CBI	CBI	CBI	CBI
CBI	CBI	CBI	CBI	CBI	CBI	CBI
CBI	CBI	CBI	CBI	CBI	CBI	CBI

Note: Design and Operating parameters are as follows:

Parameter	Design Value	Operating Value Sample Set #1	Operating Value Sample Set #2
CBI	CBI	CBI	CBI
CBI	CBI	CBI	CBI
CBI	CBI	CBI	CBI
CBI	CBI	CBI	CBI

CBI - Confidential Business Information.

5. IDENTIFICATION OF BEST DEMONSTRATED AVAILABLE TECHNOLOGY (BDAT)

This section presents the Agency's rationale for determining the best demonstrated available technology (BDAT) for K011/K013/K014 nonwastewaters and wastewaters.

To determine BDAT, the Agency examines all available performance data on technologies that are identified as demonstrated to determine (using statistical techniques) whether one or more of the technologies performs significantly better than the others. All performance data used for determination of best technology must first be adjusted for accuracy, as discussed in EPA's publication, Methodology for Developing BDAT Treatment Standards. (Accuracy adjustment accounts for the ability of an analytical technique to recover a particular constituent from the waste in a particular test. The recovery of a constituent is usually determined by spiking a sample with a known amount of the target constituent and then comparing the spiked sample amounts with results from unspiked samples.) The accuracy-corrected performance data for the K011/K013/K014 wastes are presented in Tables 5-1 through 5-6 at the end of this section. BDAT must be specifically defined for all streams associated with the management of the listed waste or wastes; this pertains to the original waste as well as to any residual waste streams created by the treatment process.

The technology that performs best on a particular waste or waste treatment is then evaluated to determine whether it is "available." To be available, the technology must (1) be commercially available to any generator and (2) provide "substantial" treatment of the waste, as determined through evaluation of accuracy-adjusted data. In determining whether treatment is substantial, EPA may consider data on the performance of a waste similar to the waste in question, provided the similar waste is at least as difficult to treat. If the best technology is found to be not available, then the next best technology is evaluated, and so on.

5.1 BDAT for Nonwastewaters

As mentioned in Section 2, the K011/K013/K014 nonwastewaters contain BDAT list organics, cyanide, and BDAT list metals. These wastes can have a total organic carbon content of greater than 1 percent and a total suspended solids content of greater than 1 percent.

5.1.1 Organic and Cyanide BDAT

The two demonstrated technologies identified for organics and cyanide treatment of K011/K013/K014 nonwastewaters for which the Agency has data are rotary kiln incineration and wet air oxidation. Operating data collected during both the incineration and wet air oxidation tests show that both data sets represent the performance of systems operating within the design specifications. Therefore, all data were used in the selection of BDAT.

Next, the Agency examined both data sets to determine whether incineration performs better than wet air oxidation. The results of the comparison of incineration and wet air oxidation indicate that incineration provides better treatment for the organics and cyanide in the K011/K013/K014 nonwastewaters. Because the wet air oxidation data are confidential, reasons for this decision are presented as confidential business information and are located in the RCRA CBI docket.

Using the incineration performance data, EPA's determination of substantial treatment for organics is based on the reduction of BDAT list organic constituents from levels as high as 61 mg/kg to nondetectable levels of less than 0.01 mg/kg in the ash residual. EPA's determination of substantial treatment for cyanide is based on the reduction of total cyanide from levels as high as 2,000 mg/kg to levels of less than 38 mg/kg in the ash. The concentrations of cyanide in the ash residual may actually be lower than the values reported, but the complex matrix made the analysis extremely difficult.

The Agency believes that these reductions are substantial and that incineration is available to treat organics and cyanide present in K011/K013/K014 nonwastewaters because it is commercially available. Therefore, incineration represents BDAT for the organics and cyanide present in the K011/K013/K014 nonwastewaters.

5.1.2 Metals BDAT

Treatment of K011/K013/K014 nonwastewaters generates an ash residual that may require metals treatment. For the BDAT list metals in the K011/K013/K014 ash residual, the only identified treatment technology on which the Agency has data is stabilization. Thus, stabilization is the "best" BDAT list metals treatment technology for the K011/K013/K014 ash residual.

Next, EPA deleted the WES stabilization because it did not show substantial reduction of the metal constituents in the leachate. At this time the Agency has not reviewed the design and operating data for the WES stabilization tests This data may help explain why the WES stabilization process does not show substantial reduction of metal constituents in the leachate. Currently, the Agency believes that different binders and binder ratios could be used to achieve effective treatment for K011/K013/K014 nonwastewaters. This belief is based on the fact that the F006 waste, a more difficult waste to stabilize, was treated effectively when using stabilization. The Agency is requesting comment concerning the stabilization of the K011/K013/K014 nonwastewaters.

Data collected on the treatment of F006 are presented in the Best Demonstrated Available Technology (BDAT) Background Document for F006. Using these data, EPA determined that stabilization represents BDAT for the metals present in K011/K013/K014 nonwastewaters.

5.2 BDAT for Wastewaters

The characterization data presented in Section 2 reveal that the K011/K013/K014 wastewaters contain BDAT list organics, cyanide, and BDAT list metals. Consequently, they may require treatment of all three categories of constituents. The wastewaters usually contain less than 1 percent total organic carbon and less than 1 percent total suspended solids.

5.2.1 Organic BDAT

The Agency has organic treatment data for K011/K013/K014 wastewaters using wet air oxidation and wet air oxidation followed by biological treatment. For both systems, the treatment performance data for wet air oxidation shown in Table 4-3 were used to determine BDAT. These data show that there was little oxidation of acetonitrile with the exception of the test run at 280°C. The acrylamide results indicate good removal at all temperatures. Since the tests were conducted to determine the optimum operating temperature, EPA concluded that the tests run at 200°C and 240°C were indicative of a poorly operated system and did not consider these data in the selection of BDAT.

Next, using the one data point for wet air oxidation and the biological treatment data, the Agency examined the data to determine whether wet air oxidation followed by biological treatment performs better than wet air oxidation alone. The results of the comparison of wet air oxidation followed by biological treatment and wet air oxidation alone indicate that wet air oxidation followed by biological treatment provides better treatment for acrylonitrile in the K011/K013/K014 mixed wastewater than does wet air oxidation alone. Therefore, wet air oxidation followed by biological treatment is "best."

Wet air oxidation followed by biological treatment is "available" because it is commercially available and it substantially reduces the hazardous BDAT organic constituents in the waste. EPA's determination of substantial treatment is based on the reduction of acrylonitrile from 415 to 0.05 ppm.

Since wet air oxidation followed by biological treatment is demonstrated, best, and available for treatment of organics in the K011/K013/K014 wastewaters, this treatment train represents BDAT.

5.2.2 Cyanide BDAT

The only demonstrated technology for treatment of cyanide in K011/K013/K014 wastewaters for which the Agency has data is wet air oxidation. Hence, wet air oxidation is the "best" cyanide treatment technology for K011/K013/K014 wastewaters.

The Agency evaluated the data for treatment of cyanide collected during the K011/K013/K014 treatment test. The Agency believes that for the purposes of cyanide treatment, the operating pressure was too low, which consequently caused poor reductions. This belief is supported by the data in Table 4-4, which indicate that higher pressures provide nondetectable levels of cyanide when treating other cyanide-containing wastes. Therefore, EPA did not consider the K011/K013/K014 treatment data in the determination of BDAT.

Next, EPA evaluated the wet air oxidation data for a cyanide-containing waste believed to be more difficult to treat than the K011/K013/K014 wastewaters. These data are presented in Table 4-4. The Agency believes that the data in Sample Set Number 1 represent poor operation. This assumption is based on the belief that since the untreated concentration of total cyanide in Sample Number 1 is higher than that in the other samples (probably because of poor mixing), the residence time should have been longer. All of the other five data sets were used to determine substantial treatment. EPA's determination of substantial treatment is based on the reduction of total cyanide in the wastewater from 28,800 mg/l to a nondetectable level of less than 0.25 mg/l.

The Agency believes that these reductions are substantial and that wet air oxidation is available to treat the cyanide present in K011/K013/K014 wastewaters because it is commercially available. Therefore, wet air oxidation represents BDAT for the cyanide present in the K011/K013/K014 wastewaters.

5.2.3 Metals BDAT

The only demonstrated technology identified for treatment of metals in K011/K013/K014 wastewaters for which the Agency has data is lime precipitation followed by dewatering. The Agency has no reason to expect that the other chemical precipitation processes could improve the level of performance; therefore, lime precipitation followed by dewatering is the "best" performing technology. As discussed earlier, EPA does not have treatment data for K011/K013/K014 wastewaters; however, EPA does have treatment data for a metals-containing wastewater (K062) believed to be similar to K011/K013/K014 wastewaters.

Data collected by the Agency on treatment of K062 are presented in the Best Demonstrated Available Technology (BDAT) Background Document for K062. Using these data, EPA determined that lime precipitation followed by dewatering represents BDAT for the metals present in K011/K013/K014 wastewaters.

Table 5-1 Summary of Accuracy Adjustment of Performance Data for Incineration of K011/K013/K014 Nonwastewater

Analytical Data	BDAT list constituent concentrations				
	Sample Set #1				
BDAT list constituents	Mixed K011/K013/K014 nonwastewaters (mg/kg)	Ash (mg/kg)	Percent recovery for matrix spike test	Accuracy correction factor	Accuracy-adjusted concentration (mg/kg)
Volatiles					
Acetonitrile	0.870	<0.5	79	1.266	<0.63
Acrylonitrile	0.410	<0.5	100	1.0	<0.5
Acrylamide	2.8	<6.5	79	1.266	<8.2
Acetone	<0.04	<0.25	100	1.0	<0.25
Benzene	57	<0.01	100	1.0	<0.01
Chloroform	0.032	<0.01	100	1.0	<0.01
Methylene chloride	0.034	<0.25	100	1.0	<0.25
Styrene	16	<0.01	100	1.0	<0.01
1,1,1-Trichloroethane	0.045	<0.01	100	1.0	<0.01
Trichloroethene	0.016	<0.01	100	1.0	<0.01
Inorganics					
Cyanide (total)	1200	10	58	1.724	17

Table 5-1 (continued)

Analytical Data	BDAT list constituent concentrations				
	Sample Set #2				
BDAT list constituents	Mixed K011/K013/K014 nonwastewaters (mg/kg)	Ash (mg/kg)	Percent recovery for matrix spike test	Accuracy correction factor	Accuracy-adjusted concentration (mg/kg)
Volatiles					
Acetonitrile	0.68	<0.5	79	1.266	<0.63
Acrylonitrile	0.52	<0.5	100	1.0	<0.5
Acrylamide	2.4	<6.5	79	1.266	<8.2
Acetone	<0.04	<0.25	100	1.0	<0.25
Benzene	61	<0.01	100	1.0	<0.01
Chloroform	0.39	<0.01	100	1.0	<0.01
Methylene chloride	0.023	<0.25	100	1.0	<0.25
Styrene	19	<0.01	100	1.0	<0.01
1,1,1-Trichloroethane	0.026	<0.01	100	1.0	<0.01
Trichloroethene	0.019	<0.01	100	1.0	<0.01
Inorganics					
Cyanide (total)	1400	5.8	58	1.724	10

Table 5-1 (continued)

Analytical Data	BDAT list constituent concentrations				
	Sample Set #3				
BDAT list constituents	Mixed K011/K013/K014 nonwastewaters (mg/kg)	Ash (mg/kg)	Percent recovery for matrix spike test	Accuracy correction factor	Accuracy-adjusted concentration (mg/kg)
Volatiles					
Acetonitrile	1.2	-	-	-	-
Acrylonitrile	0.54	-	-	-	-
Acrylamide	2.6	-	-	-	-
Acetone	0.095	-	-	-	-
Benzene	48	-	-	-	-
Chloroform	0.030	-	-	-	-
Methylene chloride	0.24	-	-	-	-
Styrene	15	-	-	-	-
1,1,1-Trichloroethane	0.029	-	-	-	-
Trichloroethene	0.014	-	-	-	-
Inorganics					
Cyanide (total)	2000	-	-	-	-

- = No value available.

Table 5-1 (continued)

Analytical Data	BDAT list constituent concentrations				
	Sample Set #4				
BDAT list constituents	Mixed K011/K013/K014 nonwastewaters (mg/kg)	Ash (mg/kg)	Percent recovery for matrix spike test	Accuracy correction factor	Accuracy-adjusted concentration (mg/kg)
Volatiles					
Acetonitrile	1.9	<0.5	79	1.266	<0.63
Acrylonitrile	0.63	<0.5	100	1.0	<0.5
Acrylamide	2.7	<6.5	79	1.266	<8.2
Acetone	<0.04	<0.25	100	1.0	<0.25
Benzene	59	<0.01	100	1.0	<0.01
Chloroform	0.034	<0.01	100	1.0	<0.01
Methylene chloride	0.041	<0.25	100	1.0	<0.25
Styrene	16	<0.01	100	1.0	<0.01
1,1,1-Trichloroethane	0.02	<0.01	100	1.0	<0.01
Trichloroethene	0.017	<0.01	100	1.0	<0.01
Inorganics					
Cyanide (total)	1300	22	58	1.724	38

Table 5-1 (continued)

Analytical Data	BDAT list constituent concentrations				
	Sample Set #5				
BDAT list constituents	Mixed K011/K013/K014 nonwastewaters (mg/kg)	Ash (mg/kg)	Percent recovery for matrix spike test	Accuracy correction factor	Accuracy-adjusted concentration (mg/kg)
Volatiles					
Acetonitrile	2.7	<0.5	79	1.266	<0.63
Acrylonitrile	0.95	<0.5	100	1.0	<0.5
Acrylamide	2.9	<6.5	79	1.266	<8.2
Acetone	0.081	<0.25	100	1.0	<0.25
Benzene	55	<0.01	100	1.0	<0.01
Chloroform	0.042	<0.01	100	1.0	<0.01
Methylene chloride	0.21	<0.25	100	1.0	<0.25
Styrene	18	<0.01	100	1.0	<0.01
1,1,1-Trichloroethane	0.032	<0.01	100	1.0	<0.01
Trichloroethene	0.018	<0.01	100	1.0	<0.01
Inorganics					
Cyanide (total)	1500	4.8	58	1.724	8.3

Table 5-1 (continued)

Analytical Data	BDAT list constituent concentrations				
	Sample Set #6				
BDAT list constituents	Mixed K011/K013/K014 nonwastewaters (mg/kg)	Ash (mg/kg)	Percent recovery for matrix spike test	Accuracy correction factor	Accuracy-adjusted concentration (mg/kg)
Volatiles					
Acetonitrile	-	-	-	-	-
Acrylonitrile	-	-	-	-	-
Acrylamide	-	-	-	-	-
Acetone	-	-	-	-	-
Benzene	-	-	-	-	-
Chloroform	-	-	-	-	-
Methylene chloride	-	-	-	-	-
Styrene	-	-	-	-	-
1,1,1-Trichloroethane	-	-	-	-	-
Trichloroethene	-	-	-	-	-
Inorganics					
Cyanide (total)	-	9.0	58	1.724	16

- = No value available.

Table 5-1 (continued)

Analytical Data	BDAT list constituent concentrations				
	Sample Set #7				
BDAT list constituents	Mixed K011/K013/K014 nonwastewaters (mg/kg)	Ash (mg/kg)	Percent recovery for matrix spike test	Accuracy correction factor	Accuracy-adjusted concentration (mg/kg)
Volatiles					
Acetonitrile	-	-	-	-	-
Acrylonitrile	-	-	-	-	-
Acrylamide	-	-	-	-	-
Acetone	-	-	-	-	-
Benzene	-	-	-	-	-
Chloroform	-	-	-	-	-
Methylene chloride	-	-	-	-	-
Styrene	-	-	-	-	-
1,1,1-Trichloroethane	-	-	-	-	-
Trichloroethene	-	-	-	-	-
Inorganics					
Cyanide (total)	-	12	58	1.724	21

- = No value available.

Reference: USEPA 1988a.

Table 5-2 Summary of Accuracy Adjustment of Performance Data for Stabilization of K011/K013/K014

			Test No. 1 - Binder: Cement Treated waste - TCLP (mg/l)					
	Untreated waste		Run 1		Run 2		Run 3	
BDAT list constituent	Total (ppm)	TCLP (mg/l)	Uncorrected value	Accuracy-adjusted value	Uncorrected value	Accuracy-adjusted value	Uncorrected value	Accuracy-adjusted value
Arsenic	19 - 140	0.014-0.23	<.005	<0.006	<.005	<0.006	<.005	0.006
Antimony	26 - 120	NA	1.30	1.35	1.23	1.28	1.20	1.25
Barium	200 - 770	0.28-0.84	.238	0.262	.249	0.273	.251	0.276
Beryllium	<0.5	NA	<.010	<0.011	<.010	<0.011	<.010	<0.011
Cadmium	2.0	<0.11	<.010	<0.012	<.010	<0.012	<.010	<0.012
Chromium	130 - 990	0.20-6.7	.018	<0.02	<.010	<0.011	<.010	<0.011
Hexavalent chromium	NA	NA	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Copper	76 - 140	0.062-0.80	.063	0.068	.090	0.097	.075	0.081
Lead	39 - 130	0.018-0.070	<.010	<0.012	<.010	<0.012	<.010	<0.012
Mercury	<1.25	<0.0042	<.0002	<0.0002	.0003	0.0003	<.0002	<0.0002
Nickel	1300 - 2700	0.11-14.0	26.0	30.2	24.4	28.4	23.9	27.8
Selenium	<1.5	0.060	<.020	<0.03	<.020	<0.03	<.020	<0.03
Silver	<3.5-5.4	<0.0023-0.0034	<.010	<0.012	<.010	<0.012	<.010	<0.012
Thallium	<1.0	NA	<.005	<0.01	<.005	<0.01	<.005	<0.01
Vanadium	<4.0-56	NA	.015	0.016	.016	0.018	.017	0.019
Zinc	120 - 1400	0.25-1.2	2.16	2.60	2.41	2.90	2.25	2.71

Table 5-2 (continued)

Test No. 1 - Binder: Cement
Treated waste - TCLP (mg/l)

BDAT list constituent	Untreated waste		Run 1		Run 2		Run 3	
	Total (ppm)	TCLP (mg/l)	Uncorrected value	Accuracy-adjusted value	Uncorrected value	Accuracy-adjusted value	Uncorrected value	Accuracy-adjusted value
Arsenic	19 - 140	0.014-0.23	<.005	<0.006	<.005	<0.006	<.005	<0.006
Antimony	26 - 120	NA	1.40	1.41	1.30	1.31	1.27	1.28
Barium	200 - 770	0.28-0.84	.213	0.227	.193	0.205	.212	0.226
Beryllium	<0.5	NA	<.010	<0.011	<.010	<0.011	<.010	<0.011
Cadmium	2.0	<0.11	<.010	<0.011	<.010	<0.011	<.010	<0.011
Chromium	130 - 990	0.20-6.7	.018	0.020	<.010	<0.011	.018	0.020
Hexavalent chromium	NA	NA	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Copper	76 - 140	0.062-0.80	.094	0.099	.087	0.092	.076	0.08
Lead	39 - 130	0.018-0.070	<.010	0.012	<.010	0.012	<.010	0.012
Mercury	<1.25	<0.0042	.00045	0.00038	<.0002	<0.0002	.0003	0.0003
Nickel	1300 - 2700	0.11-14.0	24.2	27.2	24.8	27.9	22.5	25.3
Selenium	<1.5	0.060	<.020	<0.03	<.020	<0.03	<.020	<0.03
Silver	<3.5-5.4	<0.0023-0.0034	<.010	<0.011	<.010	<0.011	<.010	<0.011
Thallium	<1.0	NA	<.005	<0.009	<.005	<0.009	<.005	<0.009
Vanadium	<4.0-56	NA	.017	0.018	.017	0.018	.018	0.018
Zinc	120 - 1400	0.25-1.2	1.99	2.26	2.20	2.50	2.15	2.44

Table 5-2 (Continued)

			Test No. 1 - Binder: Cement Treated waste - TCLP (mg/l)					
	Untreated waste		Run 1		Run 2		Run 3	
BDAT list constituent	Total (ppm)	TCLP (mg/l)	Uncorrected value	Accuracy-adjusted value	Uncorrected value	Accuracy-adjusted value	Uncorrected value	Accuracy-adjusted value
Arsenic	19 - 140	0.014-0.23	<.005	<0.005	<.005	<0.005	<.005	<0.005
Antimony	26 - 120	NA	1.32	1.38	1.30	1.35	1.24	1.29
Barium	200 - 770	0.28-0.84	.217	0.233	.193	0.208	.213	0.229
Beryllium	<0.5	NA	<.010	<0.010	<.010	<0.010	<.010	<0.010
Cadmium	2.0	<0.11	<.010	<0.011	<.010	<0.011	<.010	<0.011
Chromium	130 - 990	0.20-6.7	.010	0.011	<.010	<0.011	<.010	<0.011
Hexavalent chromium	NA	NA	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Copper	76 - 140	0.062-0.80	.042	0.044	.043	0.045	.040	0.042
Lead	39 - 130	0.018-0.070	<.010	<0.013	<.010	<0.013	<.010	<0.013
Mercury	<1.25	<0.0042	<.0002	<0.0002	<.0002	<0.0002	<.0002	<0.0002
Nickel	1300 - 2700	0.11-14.0	21.8	24.5	21.6	24.3	21.8	24.5
Selenium	<1.5	0.060	<.020	<0.026	<.020	<0.026	<.020	<0.026
Silver	<3.5-5.4	<0.0023-0.0034	<.010	<0.011	<.010	<0.011	<.010	<0.011
Thallium	<1.0	NA	<.005	<0.009	<.005	<0.009	<.005	<0.009
Vanadium	<4.0-56	NA	.022	0.023	.018	0.019	.014	0.015
Zinc	120 - 1400	0.25-1.2	2.15	2.39	2.08	2.31	2.21	2.46

NA - Not analyzed.

Reference: Memorandum from Theresa Williams, WES, to Michael Arozarena, PEI, on December 1, 1988, concerning the results of the stabilization of the K011/K013/K014 ash residue.

Table 5-3 Summary of Accuracy Adjustment of Performance Data for Wet Air Oxidation of K011/K013/K014 Wastewaters

Constituent	Sample Set No. 1 concentration			Sample Set No. 2 concentration			Sample Set No. 3 concentration		
	Untreated waste (mg/l)	Treated waste (mg/l)	Accuracy-adjusted concentration[a] (mg/l)	Untreated waste (mg/l)	Treated waste (mg/l)	Accuracy-adjusted concentration[a] (mg/l)	Untreated waste (mg/l)	Treated waste (mg/l)	Accuracy-adjusted concentration[a] (mg/l)
BDAT Organics									
Acetonitrile	575	690	690	575	560	560	575	90	90
Acrylamide	270	11	11	270	10	10	270	5	5
Acrylonitrile	24.4	0.470	0.470	24.4	<4.0	<4.0	24.4	<4.0	<4.0
BDAT list inorganics other than metals									
Cyanide (amenable)	1011	37	37	1011	11.4	11.4	1011	11.4	11.4
Cyanide (total)	1277	39	39	1277	13.6	13.6	1277	15.5	15.5

[a] No matrix spike recoveries were submitted with this performance data; therefore, it was assumed that the values have already been corrected for accuracy.

Reference: USEPA 1988h.

Table 5-4 Summary of Accuracy Adjustment of Treatment Data for Total Cyanide and Amenable Cyanide in Wastewaters using Wet Air Oxidation

	Untreated waste concentration (mg/l)	Measured treated waste concentration (mg/l)	Percent recovery for matrix spike test	Accuracy correction factor	Accuracy-adjusted concentration (mg/l)
Total cyanide					
Sample Set No. 1	33,100	11.9	52	1.923	22.9
Sample Set No. 2	27,100	<0.25	52	1.923	<0.48
Sample Set No. 3	28,300	3.22	52	1.923	6.19
Sample Set No. 4	28,800	<0.25	52	1.923	<0.48
Sample Set No. 5	28,100	<0.25	52	1.923	<0.48
Sample Set No. 6	26,000	<0.25	52	1.923	<0.48
Amenable cyanide					
Sample Set No. 1	32,000	<0.25	52	1.923	<0.48
Sample Set No. 2	25,500	<0.25	52	1.923	<0.48
Sample Set No. 3	26,900	<0.25	52	1.923	<0.48
Sample Set No. 4	27,400	<0.25	52	1.923	<0.48
Sample Set No. 5	26,600	<0.25	52	1.923	<0.48
Sample Set No. 6	25,000	<0.25	52	1.923	<0.48

Reference: USEPA 1988g.

Table 5-5 Summary of Accuracy Adjustment of Performance Data for Biological Treatment of an Acrylonitrile-Containing Wastewater

	Untreated acrylonitrile concentration (ppm)	Treated acrylonitrile concentration (ppm)	Accuracy-adjusted concentration[a] (ppm)
Sample Set #1	165	<0.05	<0.05
Sample Set #2	195	<0.05	<0.05
Sample Set #3	164	<0.05	<0.05
Sample Set #4	137	<0.05	<0.05
Sample Set #5	191	<0.05	<0.05
Sample Set #6	234	<0.05	<0.05
Sample Set #7	93	<0.05	<0.05
Sample Set #8	217	<0.05	<0.05
Sample Set #9	247	<0.05	<0.05
Sample Set #10	415	<0.05	<0.05
Sample Set #11	381	<0.05	<0.05
Sample Set #12	387	<0.05	<0.05
Sample Set #13	200	<0.05	<0.05

[a] No matrix spike recoveries were submitted with this performance data; therefore, it was assumed that the values have already been corrected for accuracy.

Reference: USEPA 1987b.

Table 5-6 Summary of Accuracy Adjustment of Performance Data for Wet Air Oxidation of K011/K013/K014 Nonwastewaters

	Concentration									
	Sample Set No. 1					Sample Set No. 2				
Constituent	Untreated Waste Total (mg/l)	Treated Solids Total (mg/l)	Accuracy adjusted concentration (mg/l)	Treated Wastewater Total (mg/l)	Accuracy adjusted concentration (mg/l)	Untreated Waste Total (mg/l)	Treated Solids Total (mg/l)	Accuracy adjusted concentration (mg/l)	Treated Wastewater Total (mg/l)	Accuracy adjusted concentration (mg/l)
CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI
CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI
CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI
CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI
CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI
CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI
CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI
CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI
CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI
CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI
CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI	CBI

CBI - Confidential Business Information.

6. SELECTION OF REGULATED CONSTITUENTS

This section presents the rationale for the selection of regulated constituents for the treatment of K011/K013/K014 wastes.

Constituents selected for regulation must satisfy the following criteria:

1. They must be on the BDAT list of regulated constituents. (Presence on the BDAT list implies the existence of approved techniques for analyzing the constituent in treated waste matrices.)
2. They must be present in, or be suspected of being present in, the untreated waste. For example, in some cases, analytical difficulties (such as masking) may prevent a constituent from being identified in the untreated waste, but its identification in a treatment residual may lead the Agency to conclude that it is present in the untreated waste.
3. Where performance data are transferred, the selected constituents must be easier to treat than the waste constituent(s) from which performance data are transferred. Factors for assessing ease of treatment vary according to the technology of concern. For instance, for incineration the factors include bond dissociation energy, thermal conductivity, and boiling point.

From the group of constituents that are eligible to be regulated, EPA may select a subset of constituents as representative of the broader group. For example, out of a group of constituents that react similarly to treatment, the Agency might name only those that are the most difficult to treat as regulated constituents for the purpose of setting a standard.

6.1 Identification of Constituents in the Untreated Waste and Waste Residuals

The first step in selecting candidate constituents to be regulated is to identify the BDAT list constituents present in the K011/K013/K014 wastes in quantities treatable by the selected BDAT. Table 6-1 (at the end of this section) shows which of the 231 BDAT list constituents were detected, not detected, and not analyzed for in the K011/K013/K014 nonwastewaters, incinerator ash residual, K011/K013/K014 wastewaters, and wet air oxidation effluent. In addition to reviewing the constituents detected in the waste streams as summarized in Table 6-1, the Agency evaluated all available characterization data presented in Section 2 and the waste-generating process to identify constituents that may generally be present in the waste but were not present in the tested K011/K013/K014 wastewaters and nonwastewaters. Table 6-2 presents all constituents known to be present in any K011/K013/K014 waste and treatment residuals.

6.2 Determination of Significant Treatment from BDAT

The next step in selecting the constituents to be regulated is to identify those constituents in the waste that were significantly treated by the technology designated as BDAT. The determined BDAT for organic and cyanide treatment of K011/K013/K014 nonwastewaters is rotary kiln incineration. The BDAT for BDAT list metals present in the ash residual is stabilization. For cyanide treatment of the K011/K013/K014 wastewaters, wet air oxidation is the selected BDAT. The selected BDAT for organics treatment of K011/K013/K014 wastewaters is wet air oxidation followed by biological treatment, and the BDAT for BDAT list metals treatment of K011/K013/K014 wastewaters is lime precipitation followed by vacuum filtration.

6.2.1 BDAT List Organic Constituents and Inorganics Other Than Metals

The incineration data presented in Table 4-1 demonstrate significant treatment for cyanides, benzene, and styrene. The concentrations of the other BDAT list organics in the untreated wastes are too low to demonstrate significant reduction. However, as discussed in the incineration write-up presented in Appendix B, the Agency is using theoretical bond energies as a surrogate for measuring combustibility. In general, the higher the bond energy for a constituent, the more difficult it is to combust. Of all the BDAT list organics determined to be present in K011/K013/K014 wastes (as shown in the waste characterization data in Section 2 and the performance data in Section 4), styrene ranks as the most difficult to treat based on its high bond energy (see Table 6-3). Since this constituent was significantly treated to nondetectable concentrations in the treatment residuals, EPA believes that the other organic constituents can also be significantly treated to nondetectable levels if they are present in high concentrations in the untreated waste. Therefore, all BDAT list organic constituents expected to be present in the K011/K013/K014 nonwastewaters will be considered for regulation. (Table 6-3 shows the calculated bond energies for the candidate organic constituents.)

Fluoride and sulfide were detected in the K011/K013/K014 nonwastewater untreated waste and treated waste streams. Since fluoride and sulfide were detected at high concentrations in the incineration treatment residuals, it does not appear that incineration is BDAT for sulfide and fluoride. Therefore, these two constituents are not being regulated at this time as the Agency currently has not completed its evaluation of treatment information for sulfide and fluoride.

The Agency has performance data for cyanide, acetonitrile, acrylamide, and acrylonitrile using wet air oxidation. This treatment process demonstrates significant treatment for all four constituents. It is believed that the other BDAT list organic constituents determined to be present in some K011/K013/K014 wastewaters can also be reduced to concentrations that are amenable to biological treatment. This is because the other BDAT list organic constituents are either aliphatic or simple nonhalogenated aromatic hydrocarbons that should be as easy to oxidize when using wet air oxidation. The Agency has biological treatment performance data only for acrylonitrile. However, the Agency has no reason to believe that when using biological treatment, the other organic constituents known to be present in K011/K013/K014 wastewaters cannot achieve the same level of treatment performance achieved by acrylonitrile. This is because the other BDAT list organic constituents are either simple aliphatic or nonhalogenated aromatic hydrocarbons that should be no more difficult to treat with biological treatment than acrylonitrile. Hence, the EPA will consider for regulation all the BDAT list organic constituents determined to be present in the K011/K013/K014 wastewaters.

6.2.2 BDAT List Metals

Incineration of the cyanide and organics present in the K011/K013/K014 nonwastewater generates an ash residual that may require treatment for metals. The stabilization data for F006 demonstrate significant treatment for the three BDAT metals (i.e., nickel, zinc, and chromium) determined to be present in treatable concentrations in the K011/K013/K014 nonwastewaters.

Wet air oxidation of K011/K013/K014 wastewater generates a wastewater effluent. Analytical results from characterization samples (see Table 2-5) of untreated wastewaters show that few metals are present in the untreated wastewater in quantities that could be treated by chemical precipitation and sludge dewatering. The only metals present in treatable quantities are barium and nickel. Other BDAT list metals were eliminated from consideration as regulated constituents since they are present in low concentrations and cannot be significantly treated by the technologies designated as BDAT.

6.3 Rationale for Selection of Regulated Constituents

Table 6-2 presents all of the candidate constituents that were detected in the untreated waste and treated with the identified BDAT. Note that all constituents could be regulated; however, the Agency believes that regulation of fewer constituents will still ensure effective treatment of all constituents.

The Agency selected acrylonitrile, acetonitrile, acrylamide, and benzene as the BDAT organic constituents for regulation. These organic constituents were present in the untreated waste in large quantities relative to the presence of the other constituents. Cyanide has been selected for regulation because of its high concentration in the untreated K011/K013/K014 wastes. The only metal selected for regulation is nickel because it is believed that this metal is most commonly found in the highest concentrations.

The Agency believes that regulation of the constituents selected will ensure that treatment occurs for the remaining BDAT list organic and metal candidates since BDAT treatment of the selected constituents will, at the same time, effectively treat those constituents not selected. Table 6-2 presents the selected regulated constituents for the K011/K013/K014 wastes.

Table 6-1 BDAT Constituents Detected or Not Detected in the K011/K013/K014 Wastes and Waste Residuals

BDAT reference no.	Parameter	CAS no.	K011/K013/K014 nonwastewater	Incinerator ash residual	K011/K013/K014 wastewaters	Wet air oxidation wastewater effluent
	Volatile Organics					
222	Acetone	67-64-1	D	ND	ND	ND
1	Acetonitrile	75-05-8	D	ND	D	D
2	Acrolein	107-02-8	ND	ND	ND	ND
	Acrylamide	79-06-1	D	ND	D	D
3	Acrylonitrile	107-13-1	D	ND	D	D
4	Benzene	71-43-2	D	ND	ND	ND
5	Bromodichloromethane	75-27-4	ND	ND	NA	NA
6	Bromomethane	74-83-9	ND	ND	ND	ND
223	n-Butyl alcohol	71-36-3	ND	ND	NA	NA
7	Carbon tetrachloride	56-23-5	ND	ND	ND	ND
8	Carbon disulfide	75-15-0	ND	ND	NA	NA
9	Chlorobenzene	108-90-7	ND	ND	ND	ND
10	2-Chloro-1,3-butadiene	108-90-7	ND	ND	NA	NA
11	Chlorodibromomethane	108-90-7	ND	ND	NA	NA
12	Chloroethane	75-00-3	ND	ND	ND	ND
13	2-Chloroethyl vinyl ether	110-75-8	ND	ND	ND	ND
14	Chloroform	67-66-3	D	ND	ND	ND
15	Chloromethane	74-87-3	ND	ND	ND	ND
16	3-Chloropropene	107-05-1	ND	ND	NA	NA
17	1,2-Dibromo-3-chloropropane	96-12-8	ND	ND	NA	NA
18	1,2-Dibromoethane	106-93-4	ND	ND	NA	NA
19	Dibromomethane	74-95-3	ND	ND	NA	NA
20	Trans-1,4-Dichloro-2-butene	110-57-6	ND	ND	NA	NA
21	Dichlorodifluoromethane	75-71-8	ND	ND	NA	NA
22	1,1-Dichloroethane	75-35-3	ND	ND	ND	ND
23	1,2-Dichloroethane	105-06-2	ND	ND	ND	ND
24	1,1-Dichloroethylene	75-35-4	ND	ND	ND	ND
25	Trans-1,2-Dichloroethene	156-60-5	ND	ND	ND	ND
26	1,2-Dichloropropane	78-87-5	NF	ND	ND	ND
27	Trans-1,3-Dichloropropene	10061-02-6	ND	ND	ND	ND
28	cis-1,3-Dichloropropene	10061-01-5	ND	ND	ND	ND
29	1,4-Dioxane	123-91-1	ND	ND	NA	NA
224	2-Ethoxyethanol	110-80-5	ND	ND	NA	NA
225	Ethyl acetate	141-78-6	ND	ND	NA	NA
226	Ethyl benzene	100-41-4	ND	ND	ND	ND

Table 6-1 (continued)

BDAT reference no.	Parameter	CAS no.	K011/K013/K014 nonwastewater	Incinerator ash residual	K011/K013/K014 wastewaters	Wet air oxidation wastewater effluent
	Volatile Organics (continued)					
30	Ethyl cyanide	10712-0	ND	ND	ND	NA
227	Ethyl ether	60-29-7	ND	ND	NA	NA
31	Ethyl methacrylate	97-63-2	ND	ND	NA	NA
214	Ethylene oxide	75-21-8	ND	ND	NA	NA
32	Iodomethane	74-88-4	ND	ND	NA	NA
33	Isobutyl alcohol	78-83-1	ND	ND	NA	NA
228	Methanol	67-56-1	ND	ND	NA	NA
34	Methyl ethyl ketone	78-93-3	ND	ND	NA	NA
229	Methyl isobutyl ketone	108-10-1	ND	ND	NA	NA
35	Methyl methacrylate	80-62-6	ND	ND	NA	NA
36	Methyl methanesulfonate	66-27-3	ND	ND	NA	NA
37	Methylacrylonitrile	126-98-7	ND	ND	NA	NA
38	Methylene chloride	75-09-2	D	ND	NA	NA
230	2-Nitropropane	79-46-9	ND	ND	NA	NA
39	Pyridine	110-86-1	ND	ND	NA	NA
40	1,1,1,2-Tetrachloroethane	630-20-6	ND	ND	NA	NA
41	1,1,2,2-Tetrachloroethane	79-34-5	ND	ND	ND	ND
42	Tetrachloroethene	127-18-4	ND	ND	ND	ND
43	Toluene	108-88-3	D	ND	ND	ND
44	Tribromomethane	75-25-2	ND	ND	NA	NA
45	1,1,1-Trichloroethane	71-55-6	D	ND	ND	ND
46	1,1,2-Trichloroethane	79-00-5	ND	ND	ND	ND
47	Trichloroethene	79-01-6	D	ND	ND	ND
48	Trichloromonofluoromethane	75-69-4	ND	ND	ND	ND
49	1,2,3-Trichloropropane	96-18-4	ND	ND	NA	NA
231	1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	ND	ND	NA	NA
50	Vinyl chloride	75-01-4	ND	ND	ND	ND
215	1,2-Xylene	97-47-6	ND	ND	NA	NA
216	1,3-Xylene	108-38-3	ND	ND	NA	NA
217	1,4-Xylene	106-44-5	ND	ND	NA	NA
	Semivolatiles					
51	Acenaphthalene	208-96-8	ND	ND	NA	NA
52	Acenaphthene	83-32-9	ND	ND	NA	NA

Table 6-1 (continued)

BDAT reference no.	Parameter	CAS no.	K011/K013/K014 nonwastewater	Incinerator ash residual	K011/K013/K014 wastewaters	Wet air oxidation wastewater effluent
	Semivolatiles (continued)					
53	Acetophenone	96-86-2	ND	ND	NA	NA
54	2-Acetylaminofluorene	53-96-3	ND	ND	NA	NA
55	4-Aminobiphenyl	92-67-1	ND	ND	NA	NA
56	Aniline	62-53-3	ND	ND	NA	NA
57	Anthracene	120-12-7	ND	ND	NA	NA
58	Aramite	140-57-8	ND	ND	NA	NA
59	Benz(a)anthracene	56-55-3	ND	ND	NA	NA
218	Benzal chloride	98-87-3	ND	ND	NA	NA
60	Benzal chloride	98-87-3	ND	ND	NA	NA
61	Benzenethiol	108-98-5	ND	ND	NA	NA
62	Benzo(a)pyrene	50-32-8	ND	ND	NA	NA
63	Benzo(b)fluoranthene	205-99-2	ND	ND	NA	NA
64	Benzo(ghi)perylene	191-24-2	ND	ND	NA	NA
65	Benzo(k)fluoranthene	207-08-9	ND	ND	NA	NA
66	p-Benzoquinone	106-51-4	ND	ND	NA	NA
67	Bis(2-chloroethoxy)methane	111-91-1	ND	ND	NA	NA
68	Bis(2-chloroethyl)ether	111-44-4	ND	ND	NA	NA
69	Bis(2-chloroisopropyl)ether	39638-32-9	ND	ND	NA	NA
70	Bis(2-ethylhexyl)phthalate	117-81-7	ND	ND	NA	NA
71	4-Bromophenyl phenyl ether	101-55-3	ND	ND	NA	NA
72	Butyl benzyl phthalate	85-68-7	ND	ND	NA	NA
73	2-sec-Butyl-4,6-dinitrophenol	88-85-7	ND	ND	NA	NA
74	p-Chloroaniline	106-47-8	ND	ND	NA	NA
75	Chlorobenzilate	510-15-6	ND	ND	NA	NA
76	p-Chloro-m-cresol	59-50-7	ND	ND	NA	NA
77	2-Chloronaphthalene	91-58-7	ND	ND	NA	NA
78	2-Chlorophenol	95-57-8	ND	ND	NA	NA
79	3-Chloropropionitrile	542-76-7	ND	ND	NA	NA
80	Chrysene	218-01-9	ND	ND	NA	NA
81	ortho-Cresol	95-48-7	ND	ND	NA	NA
82	para-Cresol	106-44-5	ND	ND	NA	NA
232	Cyclohexanone	108-94-1	ND	ND	NA	NA
83	Dibenz(a,h)anthracene	53-70-3	ND	ND	NA	NA
84	Dibenzo(a,e)pyrene	192-65-4	ND	ND	NA	NA
85	Dibenzo(a,i)pyrene	189-55-9	ND	ND	NA	NA
86	m-Dichlorobenzene	541-73-1	ND	ND	NA	NA
87	o-Dichlorobenzene	95-50-1	ND	ND	NA	NA

Table 6-1 (continued)

BDAT reference no.	Parameter	CAS no.	K011/K013/K014 nonwastewater	Incinerator ash residual	K011/K013/K014 wastewaters	Wet air oxidation wastewater effluent
	Semivolatiles (continued)					
88	p-Dichlorobenzene	106-46-7	ND	ND	NA	NA
89	3,3'-Dichlorobenzidine	91-94-1	ND	ND	NA	NA
90	2,4-Dichlorophenol	120-83-2	ND	ND	NA	NA
91	2,6-Dichlorophenol	87-65-0	ND	ND	NA	NA
92	Diethyl phthalate	84-66-2	ND	ND	NA	NA
93	3,3'-Dimethoxybenzidine	119-90-4	ND	ND	NA	NA
94	p-Dimethylaminoazobenzene	60-11-7	ND	ND	NA	NA
95	3,3'-Dimethylbenzidine	119-93-7	ND	ND	NA	NA
96	2,4-Dimethylphenol	105-67-9	ND	ND	NA	NA
97	Dimethyl phthalate	131-11-3	ND	ND	NA	NA
98	Di-n-butyl phthalate	84-74-2	ND	ND	NA	NA
99	1,4-Dinitrobenzene	100-25-4	ND	ND	NA	NA
100	4,6-Dinitro-o-cresol	534-52-1	ND	ND	NA	NA
101	2,4-Dinitrophenol	51-28-5	ND	ND	NA	NA
102	2,4-Dinitrotoluene	121-14-2	ND	ND	NA	NA
103	2,6-Dinitrotoluene	606-20-2	ND	ND	NA	NA
104	Di-n-octyl phthalate	117-84-0	ND	ND	NA	NA
105	Di-n-propylnitrosamine	621-64-7	ND	ND	NA	NA
106	Diphenylamine	122-39-4	ND	ND	NA	NA
219	Diphenylnitrosamine	86-30-6	ND	ND	NA	NA
107	1,2-Diphenylhydrazine	122-66-7	ND	ND	NA	NA
108	Fluoranthene	206-44-0	ND	ND	NA	NA
109	Fluorene	86-73-7	ND	ND	NA	NA
110	Hexachlorobenzene	118-74-1	ND	ND	NA	NA
111	Hexachlorobutadiene	87-68-3	ND	ND	NA	NA
112	Hexachlorocyclopentadiene	77-47-4	ND	ND	NA	NA
113	Hexachloroethane	67-72-1	ND	ND	NA	NA
114	Hexachlorophene	70-30-4	ND	ND	NA	NA
115	Indeno(1,2,3-cd)pyrene	193-39-5	ND	ND	NA	NA
116	Isosafrole	120-58-1	ND	ND	NA	NA
117	Methapyrilene	91-80-5	ND	ND	NA	NA
118	3-Methylcholanthrene	56-49-5	ND	ND	NA	NA
119	4,4'-Methylenebis		ND	ND	NA	NA
120	(2-chloroaniline)	101-14-4	ND	ND	NA	NA
121	Naphthalene	91-20-3	ND	ND	NA	NA
122	1,4-Naphthoquinone	130-15-4	ND	ND	NA	NA
123	1-Naphthylamine	134-32-7	ND	ND	NA	NA

Table 6-1 (continued)

BDAT reference no.	Parameter	CAS no.	K011/K013/K014 nonwastewater	Incinerator ash residual	K011/K013/K014 wastewaters	Wet air oxidation wastewater effluent
	Semivolatiles (continued)					
124	2-Naphthylamine	91-59-8	ND	ND	NA	NA
125	p-Nitroaniline	100-01-6	ND	ND	NA	NA
126	Nitrobenzene	98-95-3	ND	ND	NA	NA
127	4-Nitrophenol	100-02-7	ND	ND	NA	NA
128	N-Nitrosodi-n-butylamine	924-16-3	ND	ND	NA	NA
129	N-Nitrosodiethylamine	55-18-5	ND	ND	NA	NA
130	N-Nitrosodimethylamine	62-75-9	ND	ND	NA	NA
131	N-Nitrosomethylethylamine	10595-95-6	ND	ND	NA	NA
132	N-Nitrosomorpholine	59-89-2	ND	ND	NA	NA
133	N-Nitrosopiperidine	100-75-4	ND	ND	NA	NA
134	n-Nitrosopyrrolidine	930-55-2	ND	ND	NA	NA
135	5-Nitro-o-toluidine	99-65-8	ND	ND	NA	NA
136	Pentachlorobenzene	608-93-5	ND	ND	NA	NA
137	Pentachloroethane	76-01-7	ND	ND	NA	NA
138	Pentachloronitrobenzene	82-68-8	ND	ND	NA	NA
139	Pentachlorophenol	87-86-5	ND	ND	NA	NA
140	Phenacetin	62-44-2	ND	ND	NA	NA
141	Phenanthrene	85-01-8	ND	ND	NA	NA
142	Phenol	108-95-2	ND	ND	NA	NA
220	Phthalic anhydride	85-44-9	ND	ND	NA	NA
143	2-Picoline	109-06-8	ND	ND	NA	NA
144	Pronamide	23950-58-5	ND	ND	NA	NA
145	Pyrene	129-00-0	ND	ND	NA	NA
146	Resorcinol	108-46-3	ND	ND	NA	NA
147	Safrole	94-59-7	ND	ND	NA	NA
148	1,2,4,5-Tetrachlorobenzene	95-94-3	ND	ND	NA	NA
149	2,3,4,6-Tetrachlorophenol	58-90-2	ND	ND	NA	NA
150	1,2,4-Trichlorobenzene	120-82-1	ND	ND	NA	NA
151	2,4,5-Trichlorophenol	95-95-4	ND	ND	NA	NA
152	2,4,6-Trichlorophenol	88-06-2	ND	ND	NA	NA
153	Tris(2,3-dibromopropyl) phosphate	126-72-7	ND	ND	NA	NA
	Metals					
154	Antimony	7440-36-0	ND	NA	ND	ND
155	Arsenic	7440-38-2	D	D	ND	ND

Table 6-1 (continued)

BDAT reference no.	Parameter	CAS no.	K011/K013/K014 nonwastewater	Incinerator ash residual	K011/K013/K014 wastewaters	Wet air oxidation wastewater effluent
	Metals (continued)					
156	Barium	7440-39-3	D	D	D	D
157	Beryllium	7440-41-7	ND	NA	ND	ND
158	Cadmium	7440-43-9	D	ND	ND	D
159	Chromium	7440-47-32	D	D	D	D
160	Copper	7440-50-8	D	D	D	D
221	Hexavalent Chromium	NA	NA	NA	NA	NA
161	Lead	7439-92-1	D	D	D	D
162	Mercury	7439-97-6	ND	ND	D	ND
163	Nickel	7440-02-0	D	D	D	D
164	Selenium	7782-49-2	ND	D	D	ND
165	Silver	7440-22-4	ND	D	D	ND
166	Thallium	7440-28-0	ND	NA	D	ND
167	Vanadium	7440-62-2	ND	NA	ND	D
168	Zinc	7440-66-6	D	D	D	D
	Inorganics					
169	Cyanide	57-12-5	D	ND	D	D
170	Fluoride	16964-48-8	D	D	NA	NA
171	Sulfide	8496-25-8	ND	D	NA	NA
	Organochlorine Pesticides					
172	Aldrin	309-00-2	ND	ND	NA	NA
173	alpha-BHC	319-84-6	ND	ND	NA	NA
174	beta-BHC	319-85-7	ND	ND	NA	NA
175	delta-BHC	319-86-8	ND	ND	NA	NA
176	gamma-BHC	58-89-9	ND	ND	NA	NA
177	Chlordane	57-74-9	ND	ND	NA	NA
178	DDD	72-54-8	ND	ND	NA	NA
179	DDE	72-55-9	ND	ND	NA	NA
180	DDT	50 29-3	ND	ND	NA	NA
181	Dieldrin	60-57-1	ND	ND	NA	NA
182	Endosulfan I	939-98-8	ND	ND	NA	NA
183	Endosulfan II	33213-6-5	ND	ND	NA	NA
184	Endrin	72-20-8	ND	ND	NA	NA
185	Endrin aldehyde	7421-93-4	ND	ND	NA	NA

Table 6-1 (continued)

BDAT reference no.	Parameter	CAS no.	K011/K013/K014 nonwastewater	Incinerator ash residual	K011/K013/K014 wastewaters	Wet air oxidation wastewater effluent
	Organochlorine Pesticides (continued)					
186	Heptachlor	76-44-8	ND	ND	NA	NA
187	Heptachlor epoxide	1024-57-3	ND	ND	NA	NA
188	Isodrin	465-73-6	ND	ND	NA	NA
189	Kepone	143-50-0	ND	ND	NA	NA
190	Methoxyclor	72-43-5	ND	ND	NA	NA
191	Toxaphene	8001-35-2	ND	ND	NA	NA
	Phenoxyacetic Acid Herbicides					
192	2,4-Dichlorophenoxyacetic acid	94-75-7	ND	ND	NA	NA
193	Silvex	93-72-1	ND	ND	NA	NA
194	2,4,5-T	93-76-5	ND	ND	NA	NA
	Organophosphorous Insecticides					
195	Disulfoton	298-04-4	ND	ND	NA	NA
196	Famphur	52-85-7	ND	ND	NA	NA
197	Methyl parathion	298-00-0	D	ND	NA	NA
198	Parathion	56-38-2	ND	ND	NA	NA
199	Phorate	298-02-2	D	ND	NA	NA
	PCBs					
200	Aroclor 1016	12674-11-2	ND	ND	NA	NA
201	Aroclor 1221	11104-28-2	ND	ND	NA	NA
202	Aroclor 1232	11141-16-5	ND	ND	NA	NA
203	Aroclor 1242	53469-21-9	ND	ND	NA	NA
204	Aroclor 1248	12672-29-6	ND	ND	NA	NA
205	Aroclor 1254	11097-69-1	ND	ND	NA	NA
206	Aroclor 1260	11096-82-5	ND	ND	NA	NA
	Dioxins and Furans					
207	Hexachlorodibenzo-p-dioxins	NA	ND	ND	NA	NA
208	Hexachlorodibenzofuran	NA	ND	ND	NA	NA
209	Pentachlorodibenzo-p-dioxins	NA	ND	ND	NA	NA
210	Pentachlorodibenzofuran	NA	ND	ND	NA	NA

Table 6-1 (continued)

BDAT reference no.	Parameter	CAS no.	K011/K013/K014 nonwastewater	Incinerator ash residual	K011/K013/K014 wastewaters	Wet air oxidation wastewater effluent
	Dioxins and Furans (continued)					
211	Tetrachlorodibenzo-p-dioxins	NA	ND	ND	NA	NA
212	Tetrachlorodibenzofuran	NA	ND	ND	NA	NA
213	2,3,7,8-Tetrachlorodibenzo-p-dioxin	NA	ND	ND	NA	NA

NL = Not on list at the time of analysis
ND = Not detected
D = Detected
NA = Not applicable

Reference: USEPA 1988h.

Table 6-2 Constituents for Regulation

Candidate BDAT list constituents determined to be present in K011/K013/K014 wastes	Eliminated based on treatability[a]	Selected constituents
Volatiles		
Acetone		
Acetonitrile		X
Acrolein		
Acrylonitrile		X
Acrylamide		X
Benzene		X
Chloroform		
Dichlorodifluoromethane		
Ethyl cyanide		
Methylene chloride		
Pyridine		
Styrene		
1,1,1-Trichloroethane		
Trichloroethene		
Semivolatiles		
Phenol		
2-Picoline		
Inorganics Other Than Metals		
Cyanide		X
Fluoride	X	
Sulfide	X	
Metals		
Antimony	X	
Arsenic	X	
Barium		
Cadmium	X	
Chromium		
Copper	X	
Nickel		X
Lead	X	
Zinc		

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[a] Constituents eliminated because they were determined not to be present in treatable quantities and therefore cannot be signficantly treated by the technologies designated as BDAT.

Table 6-3 Calculated Bond Energies for the Organic Constituents

Constituent	Calculated bond energy[a] (Kcal/mol)
Acetone	945
Acrolein	805
Acetonitrile	590
Acrylamide	985
Acrylonitrile	860
Benzene	1320
Chloroform	340
Dichlorodifluoromethane	390
Ethyl cyanide	880
Methylene chloride	355
Pyridine	1210
Phenol	1421
1,1,1-Trichloroethane	625
Trichloroethene	485
Styrene	1750

[a] Calculations are based on information in Sanderson 1971.

7. DEVELOPMENT OF THE PROPOSED BDAT TREATMENT STANDARDS

The Agency bases the proposed treatment standards for the regulated constituents on the performance of well-designed and well-operated BDAT treatment systems. These proposed standards must account for analytical limitations in available performance data and must be adjusted for variabilities related to treatment, sampling, and analytical techniques and procedures.

The proposed BDAT standards are determined for each constituent by multiplying the arithmetic mean of accuracy-adjusted constituent concentrations detected in treated waste by a "variability factor" specific to each treatment technology defined as BDAT. Accuracy adjustment of performance data was discussed in Section 5 in relation to defining "substantial treatment." Variability factors correct for normal variations in the performance of a particular technology over time. They are designed to reflect the 99th percentile level of performance that the technology achieves in commercial operation. For more information on the principles of calculating variability factors, see EPA's publication, Methodology for Developing BDAT Treatment Standards.

Where EPA has identified BDAT for a particular waste, but because of data limitations or for some other compelling reason cannot define specific treatment standards for that waste, the Agency can require the use of that treatment process as a technology standard. Similarly, where there are no known generators of a waste, or where EPA believes that the waste can be totally recycled or reused as a raw material, the Agency may specify a "no land disposal" standard, which effectively amounts to setting the performance standard at zero for all waste constituents.

In the case of K011, K013, and K014, the Agency is proposing treatment standards for regulated constituents as shown in Table 7-1.

For wastewater forms of these wastes, the proposed BDAT list organic treatment standards are based on the performance of wet air oxidation followed by biological treatment. The proposed cyanide treatment standards are based on the performance of wet air oxidation. Calculations for the proposed organic standards are presented in Table 7-2, and calculations for the proposed cyanide standards are shown in Table 7-3. The proposed BDAT list metal standard is based on the performance of lime precipitation followed by dewatering. For details on the calculation of the proposed metal treatment standard, see the Best Demonstrated Available Technology (BDAT) Background Document for K062.

For nonwastewater forms of these wastes, the proposed BDAT list organic and cyanide treatment standards are based on the performance of incineration. The calculations of the proposed organic and cyanide standards are presented in Table 7-4. The proposed BDAT list metal nonwastewater standard is based on stabilization. For details on the calculation of the proposed metal treatment standard, see the Best Demonstrated Available Technology (BDAT) Background Document for F006.

Table 7-1 Proposed BDAT Treatment Standards

BDAT Treatment Standards for K011/K013/K014 Nonwastewaters

Constituent	Maximum for any single grab sample Total composition (mg/kg)	 TCLP (mg/l)
Acetonitrile	1.8	Not Applicable
Acrylonitrile	1.4	Not Applicable
Acrylamide	23	Not Applicable
Benzene	0.03	Not Applicable
Cyanides (Total)	57	Not Applicable
Nickel	Not Applicable	0.32

BDAT Treatment Standards for K011/K013/K014 Wastewaters

Constituent	Maximum for any single grab sample Total composition (mg/l)	 TCLP (mg/l)
Acetonitrile	0.14	Not Applicable
Acrylonitrile	0.14	Not Applicable
Acrylamide	0.14	Not Applicable
Benzene	0.14	Not Applicable
Cyanides (Total)	12	Not Applicable
Cyanides (Amenable)	1.3	Not Applicable
Nickel	0.44	Not Applicable

Table 7-2 Calculation of the Proposed Wastewater Organic Treatment Standards for the Regulated Constituents Based on Wet Air Oxidation Followed by Biological Treatment Performance Data

Constituent	Treated concentration (mg/l) Sample Set No. 1	2	3	4	5	6	7	8	9	10	11	12	13	Mean (mg/l)	Variability factor	Treatment standard (mg/l)
Acetonitrile	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	2.8	0.14
Acrylonitrile	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	2.8	0.14
Acrylamide	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	2.8	0.14
Benzene	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	2.8	0.14

Table 7-3 Calculation of the Proposed Wastewater Cyanide Treatment Standards Based on Wet Air Oxidation Performance Data

	Unadjusted concentration (mg/l) Sample Set No.					Analytical	Accuracy corrected concentration (mg/l) Sample Set No.							Treatment
						Correction						Mean	Variability	standard
Constituent	1	2	3	4	5	factor	1	2	3	4	5	(mg/l)	factor	(mg/l)
Cyanide (amenable)	<0.25	<0.25	<0.25	<0.25	<0.25	1.923	<0.48	<0.48	<0.48	<0.48	<0.48	0.48	2.8	1.3
Cyanide (total)	<0.25	3.22	<0.25	<0.25	<0.25	1.923	<0.48	6.19	<0.48	<0.48	<0.48	1.62	7.09	12

Table 7-4 Calculation of the Proposed Nonwastewater Organic and Cyanide Treatment Standards for the Regulated Constituents Based on Rotary Kiln Incineration Performance Data

Constituent	Unadjusted concentration (mg/kg) Sample Set No. 1	2	3	4	5	6	7	Correction factor	Accuracy corrected concentration (mg/kg) Sample Set No. 1	2	3	4	5	6	7	Mean (mg/kg)	Variability factor	Treatment standard (mg/kg)
BDAT List Volatile Organics																		
Acetonitrile	0.5	0.5	-	0.5	0.5	-	-	1.3	0.63	0.63	-	0.63	0.63	-	-	0.63	2.8	1.8
Acrylonitrile	0.5	0.5	-	0.5	0.5	-	-	1.0	0.5	0.5	-	0.5	0.5	-	-	0.5	2.8	1.4
Acrylamide	6.5	6.5	-	6.5	6.5	-	-	1.3	8.2	8.2	-	8.2	8.2	-	-	8.2	2.8	23.
Benzene	0.01	0.01	-	0.01	0.01	-	-	1.0	0.01	0.01	-	0.01	0.01	-	-	0.01	2.8	0.03
BDAT List Inorganics Other Than Metals																		
Cyanide (total)	10	5.8	-	22	4.8	9.0	12	1.7	17	10	-	38	8.3	16	21	18.3	3.1	57

- = No value available.

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USEPA. 1988b. U.S. Environmental Protection Agency. Engineering summary report on K011, K013, and K014 wastewater characterization and treatment. Prepared by PEI Associates, Cincinnati, Ohio.

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USEPA. 1988d. U.S. Environmental Protection Agency. Best demonstrated available technology background document for cyanide wastes. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1988e. U.S. Environmental Protection Agency. Best demonstrated available technology background document for K062. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1988f. U.S. Environmental Protection Agency. Treatment technology background document. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1988g. U.S. Environmental Protection Agency. Onsite engineering report of treatment technology performance and operation for wet air oxidation of F007 at Zimpro/Passavant, Inc., in Rothschild, Wisconsin. Washington, D.C.: U.S. Environmental Protection Agency.

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USEPA. 1988i. U.S. Environmental Protection Agency. Best demonstrated available technology background document for F006. Washington, D.C.: U.S. Environmental Protection Agency.

APPENDIX A

Analytical QA/QC

The analytical methods used for analysis of the regulated constituents identified in Section 6 are listed in Table A-1. SW-846 methods (EPA's Test Methods for Evaluation of Solid Waste; Physical/Chemical Methods, SW-846, Third Edition, November 1986) were used in most cases for determining total constituent concentrations. Leachate concentrations were determined using the Toxicity Characteristics Leaching Procedure (TCLP), published in 51 FR 1750, November 7, 1986.

In some instances SW-846 allows for the use of alternative or equivalent procedures or equipment. Table A-2 presents the specific procedures or equipment used in extraction of organic compounds. The specific procedures or equipment used for analysis of organic and metal compounds are shown in Table A-3.

As stated in the introduction, all concentrations for the regulated constituents will be corrected to account for analytical interference associated with the chemical makeup of the waste matrix. The correction factor for a constituent is based on the matrix spike recovery values. Table A-4 presents the organic matrix spike recoveries used to determine the correction factor for the nonwastewater organic and cyanide data. The matrix spike recoveries used to calculate the correction factors for K011/K013/K014 wastewater cyanide concentrations are presented in Table A-5.

Table A-1 Analytical Methods for Regulated Constituents in K011/K013/K014 Wastes

Regulated constituents	Extraction method	Method number	Analytical method	Method number	Reference
Volatile					
Acetonitrile	Purge and trap	5030	Gas Chromatography/Mass Spectrometry	8240	1
Acrylonitrile	Purge and trap	5030	Gas Chromatography/Mass Spectrometry	8240	1
Acrylamide	To be determined	To be determined	To be determined	To be determined	
Benzene	Purge and trap	5030	Gas Chromatography/Mass Spectrometry	8240	1
Inorganics Other Than Metals					
Cyanide (total)	Specified in analytical method		Colorimetric	9012	1
Cyanide (free)	Specified in analytical method		Colorimetric	9012	1
Metals					
Nickel (total composition)	Specified in analytical method		Inductively Coupled Plasma Atanic Emission Spectroscopy (ICPES)	6010	1
Nickel (TCLP)	Specified in analytical method		Toxicity Characteristic Leaching Procedure (TCLP)	51 FR 1750	2

References: USEPA 1986b.
Federal Register 1986.

Table A-2 Specific Procedures or Equipment Used in Extraction of Organic Compounds When Alternatives or Equivalents Are Allowed in the SW-846 Methods

Analysis	SW-846 method	Sample aliquot	Alternatives or equivalents allowed by SW-846 methods	Specific procedures or equipment used
Purge and trap	5030	5 milliliters of liquid	• The purge and trap device to be used is specified in the method in Figure 1, the desorber to be used is described in Figures 2 and 3, and the packing materials are described in Section 4.10.2 of SW-846. The method allows equivalents of this equipment or these materials to be used.	• The purge and trap equipment and the desorber used were as specified in SW-846. The purge and trap equipment is a Teckmar LSC-2 with standard purging chambers (Supelco cat. 2-0293). The packing materials for the traps were 1/3 silica gel and 2/3 2,6-diphenylene.
			• The method specifies that the trap must be at least 25 cm long and have an inside diameter of at least 0.105 cm.	• The length of the trap was 30 cm and the diameter was 0.105 cm.
			• The surrogates recommended are toluene-d8,4-bromofluorobenzene, and 1,2-dichloroethane-d4. The recommended concentration level is 50 ug/l.	• The surrogates were added as specified in SW-846.

References: USEPA 1988a.
USEPA 1986b.

Table A-3 Specific Procedures or Equipment Used for Analysis of Organic and Metal Compounds When Alternatives or Equivalents Are Allowed in SW-846

Analysis	SW 846 Method	Sample preparation method	Alternatives or equivalents allowed in SW-846 for equipment or in procedure	Specific equipment or procedures used
Organic Compounds			Recommended GC/MS operating conditions:	Actual GC/MS operating conditions:
Gas Chromatography/ Mass Spectrometry for volatile organics	8240	5030	Electron energy: 70 ev (nominal)	Electron energy: 70 ev
			Mass range: 35-260 amu	Mass range: 35-260 amu
			Scan time: To give 5 scans/peak but not to exceed 7 sec/scan	Scan time: 2.5 sec/scan
			Initial column temperature: 45°C	Initial column temperature: 38°C
			Initial column holding time: 3 min	Initial column holding time: 2 min
			Column temperature program: 8°C/min	Column temperature program: 10°C/min
			Final column temperature: 200°C	Final column temperature: 225°C
			Final column holding time: 15 min	Final column holding time: 30 min or xylene elutes
			Injector temperature: 200-225°C	Injector temperature: 225°C
			Source temperature: According to manufacturer's specification	Source temperature: Manufacturer's recommended value of 100°C
			Transfer line temperature: 250-300°C	Transfer line temperature: 275°C
			Carrier gas: Hydrogen at 50 cm/sec or helium at 30 cm/sec	Carrier gas: Helium at 30 cm/min cm/sec
				• Additional Information on Actual System Used: Equipment: Finnegan Model 5100 GC/MS/DS system Data system: SUPERINCOS Autoquan Mode: Electron impact NBS library available Interface to MS - Jet separator
			• The column should be 6 ft x 0.1 in I.D. glass, packed with 1% SP-1000 on Carbopack B (60/80 mesh) or an equivalent.	• The column used was an 8 ft x 0.1 in I.D. glass, packed with 1% SP-1000 on Carbopack B (60/80 mesh).
			• Samples may be analyzed by purge and trap technique or by direct injection.	• The samples were analyzed using the purge and trap technique.

Table A-1. (continued)

Analysis	SW 846 method	Sample preparation method	Alternatives or equivalents allowed in SW 846 for equipment or in procedure	Specific equipment or procedures used
Total and Amenable Cyanide	9012	500 ml	Pretreatment with bismuth nitrate may be necessary if sulfides are present.	Pretreatment was not necessary.
Colorimetric			Pretreatment with sulfamic acid may be necessary if nitrites/nitrates are present.	Pretreatment was not necessary.
			A Fisher-Mulligan absorber or equivalent should be used.	An ACE smog bubbler absorber was used.
			A spectrophotometer suitable for measurements at 578 nm with a 1.0-cm cell or larger is required.	A Bausch and Lomb Model Spectronic 21 was used.
Metals				
Inductively coupled	6010		• Operate equipment following instructions provided by instrument's manufacturer.	• Equipment operated using procedures specified in the Jarrell Ash (JA) 1140 Operator's Manual.
			• For operation with organic solvents, auxiliary argon gas inlet is recommended.	• Auxiliary argon gas was not required for sample matrix.

References: USEPA 1986b.
USEPA 1988a.

Table A-4 Matrix Spike Recoveries Used to Calculate Correction Factors for K011/K013/K014 Nonwastewater Organic and Cyanide Concentrations

BDAT list constituent	Original amount found (µg/g)	Amount spiked (µg/g)	Sample		Duplicate		Accuracy correction factor[b]
			Spike result (µg/g)	Percent recovery[a]	Spike result (µg/g)	Percent recovery[a]	
Acetonitrile	ND	125	99	79	100	80	1.266
Acrolein	ND	125	100	80	36	47	2.128
Acrylonitrile	ND	125	138	110	119	108	1.000
Benzene	ND	25	35	141	206	146	1.000
Chlorobenzene	ND	25	27	107	115	107	1.000
1,1-Dichloroethene	ND	25	24.8	99	104	104	1.010
Toluene	ND	25	28	113	132	117	1.000
Trichloroethene	ND	25	26	104	109	105	1.000
Average				104		102	1.000
Acrylamide	ND	56	45	81	44	79	1.266
Cyanide (total)	ND	4.9	0	0	2.8	58	1.724

[a] Percent recovery = [(spike result - original amount)/spike added]

[b] Accuracy-correction factor = 100/percent recovery (using the lowest percent recovery values).

Reference: USEPA 1988a.

Table A-5 Matrix Spike Recoveries used to Calculate Correction Factors for K011/K013/K014 Wastewater Cyanide Concentrations

Sample number	Sample conc (µg/l)	Spike added (µg/l)	Spike result (µg/l)	Percent recovery	Spike duplicate result (µg/l)	Percent recovery	RPD
3	16.11	24.75	29.16	52.7	28.97	52.0	0.7

Reference: USEPA 1988g.

$$RPD = 100\ (\text{spike result-spike duplicate result})/(\frac{\text{spike result + spike duplicate result}}{2})$$

APPENDIX B

INCINERATION

This Appendix, consisting of a description of the incineration treatment technology, includes information relevant to the use and understanding of the background document for the K011, K013, and K014 listed hazardous wastes subject to the RCRA "Land Ban" restrictions.

It is anticipated that non-substantive changes will be made to this treatment technology description prior to publication of final "Second Thirds" Land Ban regulations. These changes will be primarily formatting and organizational in nature.

APPENDIX B

DRAFT

Technology - Incineration

This section addresses the commonly used incineration technologies: Liquid injection, rotary kiln, fluidized bed incineration, and fixed hearth. A discussion is provided regarding the applicability of these technologies, the underlying principles of operation, a technology description, waste characteristics that affect performance, and finally important design and operating parameters. As appropriate the subsections are divided by type of incineration unit.

Applicability and Use of this Technology

Liquid Injection

Liquid injection is applicable to wastes that have viscosity values sufficiently low so that the waste can be atomized in the combustion chamber. A range of literature maximum viscosity values are reported with the low being 100 SSU and the high being 10,000 SSU. It is important to note that viscosity is temperature dependent so that while liquid injection may not be applicable to a waste at ambient conditions, it may be applicable when the waste is heated. Other factors that affect the use of liquid injection are particle size and the presence of suspended solids. Both of these waste parameters can cause plugging of the burner nozzle.

Rotary Kiln/ Fluidized Bed/ Fixed Hearth

These incineration technologies are applicable to a wide range of hazardous wastes. They can be used on wastes that contain high or low total organic content, high or low filterable solids, various viscosity ranges, and a range of other waste parameters. EPA has not found these technologies to be demonstrated on wastes that are comprised essentially of metals with low organic concentrations. In addition, the Agency expects that some of the high metal content wastes may not be compatible with existing and future air emission limits without emission controls far more extensive than currently practiced.

Underlying Principles of Operation

Liquid Injection

The basic operating principle of this incineration technology is that incoming liquid wastes are volatilized and then additional heat is supplied to the waste to destabilize the chemical bonds. Once the chemical bonds are broken, these constituents react with oxygen to form carbon dioxide and water vapor. The energy needed to destabilize the bonds is referred to as the energy of activation.

Rotary Kiln and Fixed Hearth

There are two distinct principles of operation for these incineration technologies, one for each of the chambers involved. In the primary chamber, energy, in the form of heat, is transferred to the waste to achieve volatilization of the various organic waste constituents. During this volatilization process some of the organic constituents will oxidize to CO_2 and water vapor. In the secondary chamber, additional heat is supplied to overcome the energy requirements needed to destabilize the chemical bonds and allow the constituents to react with excess oxygen to form carbon dioxide and water vapor. The principle of operation for the secondary chamber is similar to liquid injection.

Fluidized Bed

The principle of operation for this incinerator technology is somewhat different than for rotary kiln and fixed hearth incineration relative to the functions of the primary and secondary chambers. In fluidized bed, the purpose of the primary chamber is not only to volatilize the wastes but also to essentially combust the waste. Destruction of the waste organics can be accomplished to a better degree in the primary chamber of this technology than for rotary kiln and fixed hearth because of 1) improved heat transfer from fluidization of the waste using forced air and 2) the fact that the fluidization process provides sufficient oxygen and turbulence to convert the organics to carbon dioxide and water vapor. The secondary chamber (referred to as the freeboard) generally does not have an afterburner; however, additional time is provided for conversion of the organic constituents to carbon dioxide, water vapor, and hydrochloric acid if chlorine is present in the waste.

Description of Incineration Technologies

Liquid Injection

The liquid injection system is capable of incinerating a wide range of gases and liquids. The combustion system has a simple design with virtually no moving parts. A burner or nozzle atomizes the liquid waste and injects it into the combustion chamber where it burns in the presence of air or oxygen. A forced draft system supplies the combustion chamber with air to provide oxygen for combustion and turbulence for mixing. The combustion chamber is usually a cylinder lined with refractory (i.e., heat resistant) brick and can be fired horizontally, vertically upward, or vertically downward. Figure 1 illustrates a liquid injection incineration system.

Rotary Kiln

A rotary kiln is a slowly rotating, refractory-lined cylinder that is mounted at a slight incline from the horizontal (see Figure 2). Solid wastes enter at the high end of the kiln, and liquid or gaseous wastes enter through atomizing nozzles in the kiln or afterburner section. Rotation of the kiln exposes the solids to the heat, vaporizes them, and allows them to combust by mixing with air. The rotation also causes the ash to move to the lower end of the kiln where it can be removed. Rotary kiln systems usually have a secondary combustion chamber or afterburner following the kiln for further combustion of the volatilized components of solid wastes.

Fluidized Bed

A fluidized bed incinerator consists of a column containing inert particles such as sand which is referred to as the bed. Air, driven by a blower, enters the bottom of the bed to fluidize the sand. Air passage through the bed promotes rapid and uniform mixing of the injected waste material within the fluidized bed. The fluidized bed has an extremely high heat capacity (approximately three times that of flue gas at the same temperature), thereby providing a large heat reservoir. The injected waste reaches ignition temperature quickly and transfers the heat of combustion back to the bed. Continued bed agitation by the

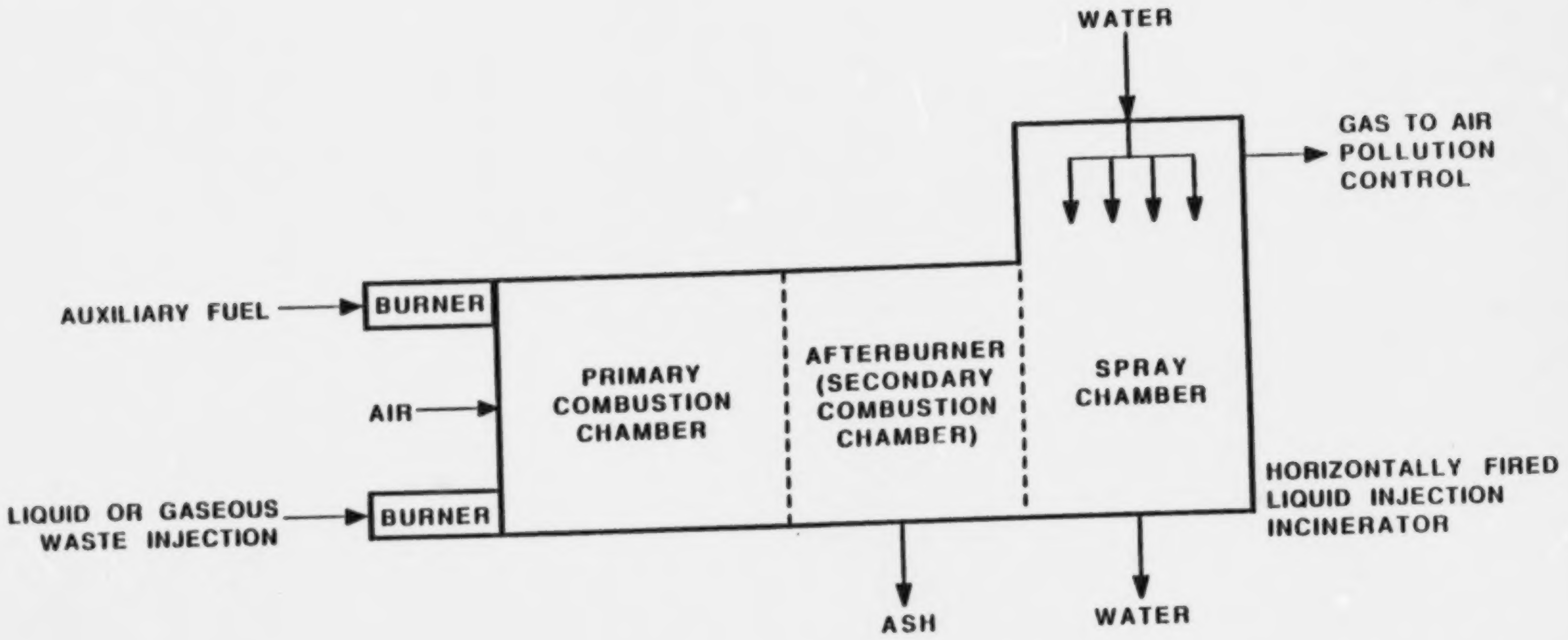
WATER
GAS TO AIR POLLUTION CONTROL
AUXILIARY FUEL
BURNER
AIR
LIQUID OR GASEOUS WASTE INJECTION
BURNER
PRIMARY COMBUSTION CHAMBER
AFTERBURNER (SECONDARY COMBUSTION CHAMBER)
SPRAY CHAMBER
HORIZONTALLY FIRED LIQUID INJECTION INCINERATOR
ASH
WATER

FIGURE 1
LIQUID INJECTION INCINERATOR

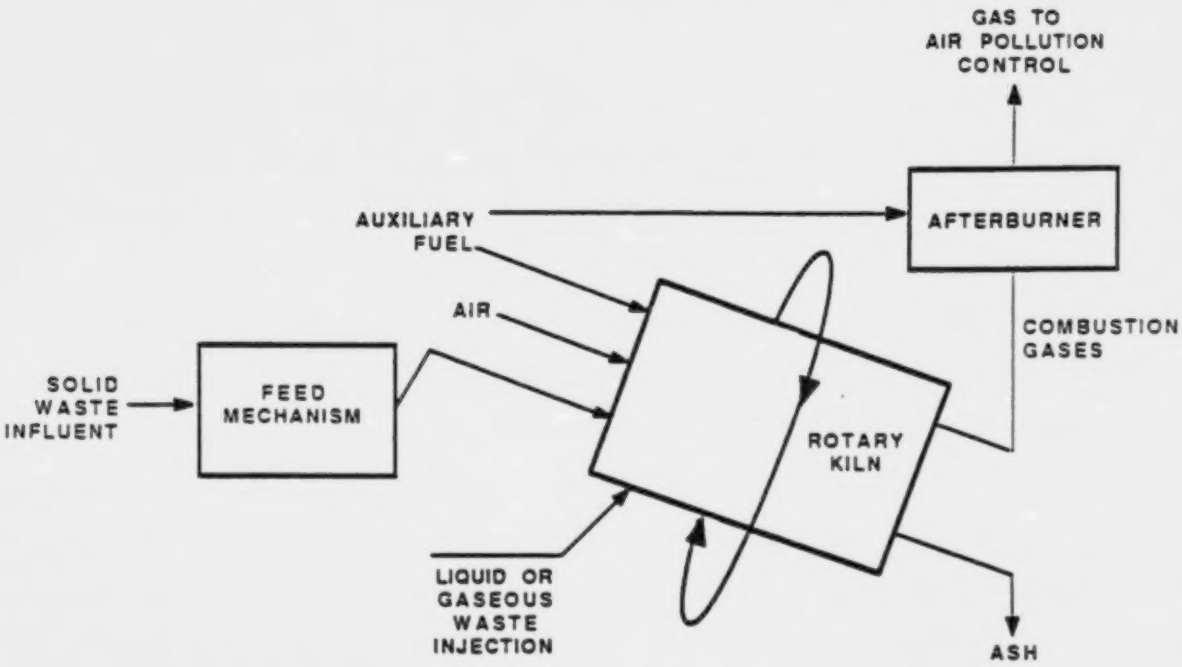
GAS TO AIR POLLUTION CONTROL
AFTERBURNER
AUXILIARY FUEL
AIR
COMBUSTION GASES
SOLID WASTE INFLUENT
FEED MECHANISM
ROTARY KILN
LIQUID OR GASEOUS WASTE INJECTION
ASH

FIGURE 2
ROTARY KILN INCINERATOR

fluidizing air allows larger particles to remain suspended in the combustion zone. (See Figure 3)

Fixed Hearth Incineration

Fixed hearth incinerators, also called controlled air or starved air incinerators, are another major technology used for hazardous waste incineration. Fixed hearth incineration is a two-stage combustion process (see Figure 4). Waste is ram-fed into the first stage, or primary chamber, and burned at less than stoichiometric conditions. The resultant smoke and pyrolysis products, consisting primarily of volatile hydrocarbons and carbon monoxide, along with the normal products of combustion, pass to the secondary chamber. Here, additional air is injected to complete the combustion. This two-stage process generally yields low stack particulate and carbon monoxide (CO) emissions. The primary chamber combustion reactions and combustion gas are maintained at low levels by the starved air conditions so that particulate entrainment and carryover are minimized.

Air Pollution Controls

Following incineration of hazardous wastes, combustion gases are generally further treated in an air pollution control system. The presence of chlorine or other halogens in the waste requires a scrubbing or absorption step to remover HCl and other halo-acids from the combustion gases. Ash in the waste is not destroyed in the combustion process. Depending on its composition, ash will either exit as bottom ash, at the discharge end of a kiln or hearth for example, or as

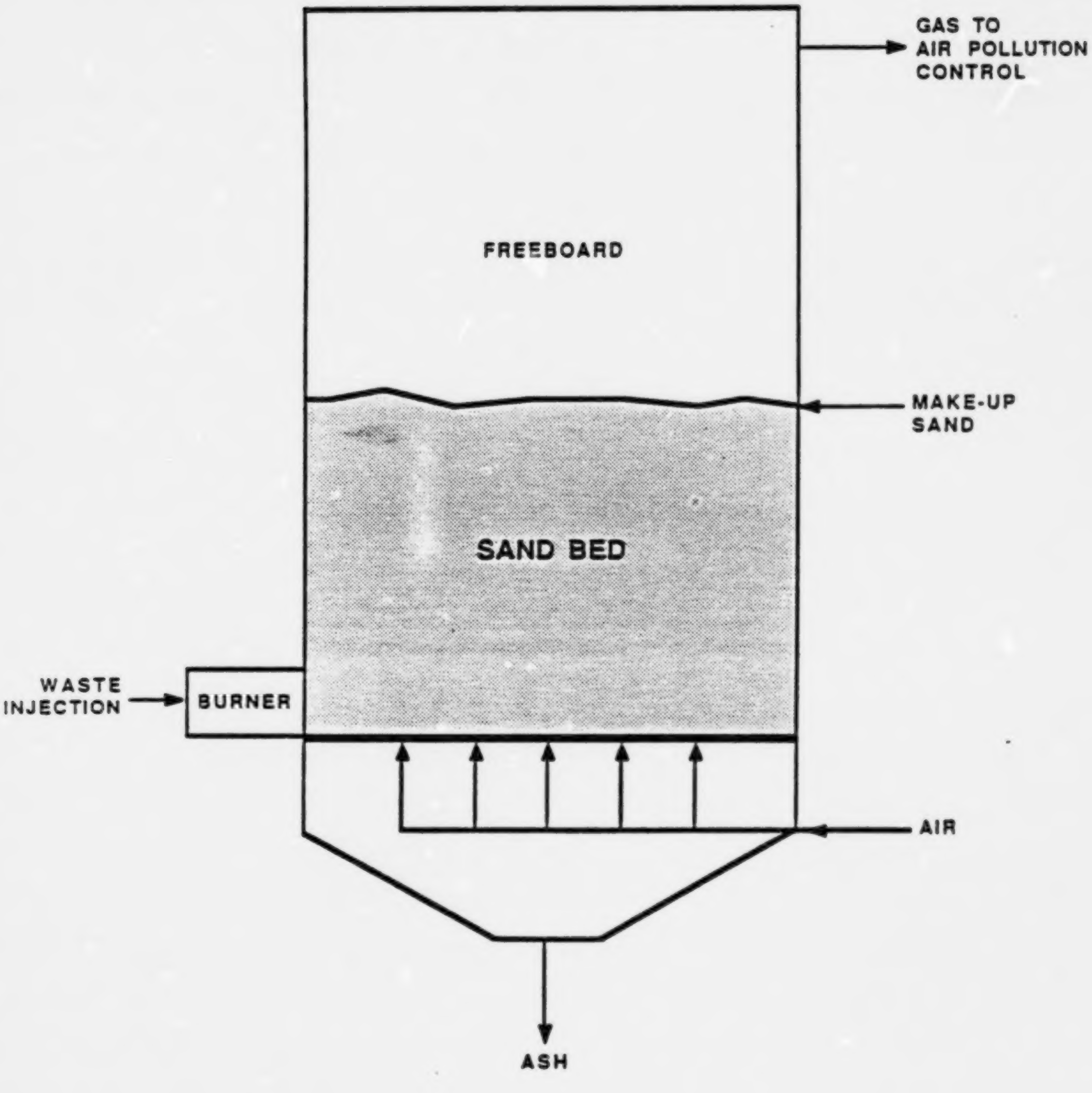
GAS TO
AIR POLLUTION
CONTROL
FREEBOARD
MAKE-UP
SAND
SAND BED
WASTE
INJECTION
BURNER
AIR
ASH

FIGURE 3
FLUIDIZED BED INCINERATOR

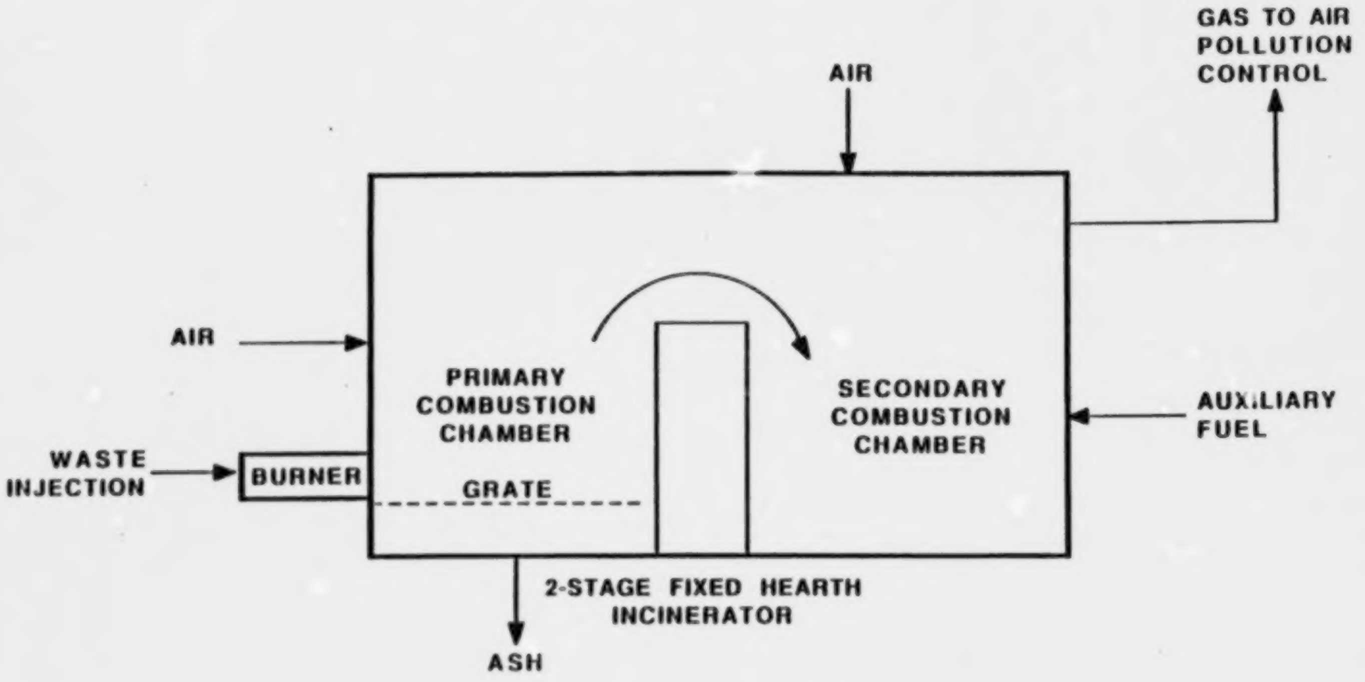
GAS TO AIR POLLUTION CONTROL
AIR
AIR
PRIMARY COMBUSTION CHAMBER
SECONDARY COMBUSTION CHAMBER
AUXILIARY FUEL
WASTE INJECTION
BURNER
GRATE
2-STAGE FIXED HEARTH INCINERATOR
ASH

FIGURE 4
FIXED HEARTH INCINERATOR

particulate matter (fly ash) suspended in the combustion gas stream. Particulate emissions from most hazardous waste combustion systems generally have particle diameters less than one micron and require high efficiency collection devices to minimize air emissions. In addition, scrubber systems provide additional buffer against accidental releases of incompletely destroyed waste products due to poor combustion efficiency or combustion upsets, such as flame outs.

Waste Characteristics Affecting Performance (WCAP)

Liquid Injection

In determining whether liquid injection is likely to achieve the same level of performance on an untested waste as a previously tested waste, the Agency will compare dissociation bond energies of the constituents in the untested and tested waste. This parameter is being used as a surrogate indicator of activation energy which, as discussed previously, destabilizes molecular bonds. In theory, the bond dissociation energy would be equal to the activation energy; however, in practice this is not always the case.Other energy effects (e.g., vibrational, the formation of intermediates, and interactions between different molecular bonds) may have a significant influence on activation energy.

Because of the shortcomings of bond energies in estimating activation energy, EPA analyzed other waste characteristic parameters to determine if these parameters would provide a better basis for transferring treatment standards from an untested waste to a tested waste. These parameters include heat of combustion, heat of formation, use of available kinetic data to predict activation energies, and general structural class. All of these were rejected for reasons provided below.

The heat of combustion only measures the difference in energy of the products and reactants; it does not provide information on the transition state (i.e., the energy input needed to initiate the reaction, see Figure 2 below). Heat of formation is used as a predictive tool for whether reactions are likely to proceed; however, there are a significant number of hazardous constituents for which these data are not available. Use of kinetic data were rejected because these data are limited and could not be used to calculate free energy values (ΔG) for the wide range of hazardous constituents to be addressed by this rule. Finally, EPA decided not to use structural classes because the Agency believes that evaluation of bond dissociation energies allows for a more direct determination of whether a constituent will be destabilized.

Rotary Kiln/Fluidized Bed/Fixed Hearth

Unlike liquid injection, these incineration technologies also generate a residual ash. Accordingly, in determining whether these technologies are likely to achieve the same level of performance on an untested waste as a previously tested waste, EPA would need to examine the waste characteristics that affect volatilization of organics from the waste, as well as, destruction of the organics, once volatilized. Relative to volatilization, EPA will examine thermal conductivity of the entire waste and boiling point of the various constituents. As with liquid injection, EPA will examine bond energies in determining whether treatment standards for scrubber water residuals can be transferred from a tested waste to an untested waste. Below is a discussion of how EPA arrived at thermal conductivity and boiling point as the best method to assess volatilization of organics from the waste; the discussion relative to bond energies is the same for these technologies as for liquid injection and will not be repeated here.

(1) Thermal Conductivity. Consistent with the underlying principles of incineration, a major factor with regard to whether a particular constituent will volatilize is the transfer of heat through the waste. In the case of rotary kiln, fluidized bed, and fixed hearth incineration, heat is transferred through the waste by three mechanisms: radiation, convection, and conduction. For a given incinerator, heat transferred through various wastes by radiation is more a function of the design and type of incinerator than the waste being treated. Accordingly, the type of waste treated will have a minimal impact on the amount of heat transferred by radiation. With regard to convection, EPA also believes that the type of heat transfer will generally be more a function of the type and design of incinerator than the waste itself. However, EPA is examining particle size as a waste characteristic that may significantly impact the amount of heat transferred to a waste by convection and thus impact volatilization of the various organic compounds. The final type of heat transfer, conduction, is the one that EPA believes will have the greatest impact on volatilization of organic constituents. To measure this characteristic, EPA will use thermal conductivity; an explanation of this parameter, as well as, how it can be measured is provided below.

Heat flow by conduction is proportional to the temperature gradient across the material. The proportionality constant is a property of the material and referred to as the thermal conductivity. (Note: The analytical method that EPA has identified for measurement of thermal conductivity is named "Guarded, Comparative, Longitudinal Heat Flow Technique"; it is described following this technology section.) In theory, thermal conductivity would always provide a good indication of whether a constituent in an untested waste would be treated to the same extent in the primary incinerator chamber as the same constituent in a previously tested waste.

In practice, thermal conductivity has some limitations in assessing the transferability of treatment standards; however, EPA has not identified a parameter that can provide a better indication of heat transfer characteristics of a waste. Below is a discussion of both the limitations associated with thermal conductivity, as well as other parameters considered.

Thermal conductivity measurements, as part of a treatability comparison for two different wastes through a single incinerator, are most meaningful when applied to wastes that are homogeneous (i.e., major constituents are essentially the same). As wastes exhibit greater degrees of non-homogeneity (e.g., significant concentration of metals in soil), then thermal conductivity becomes less accurate in predicting treatability because the measurement essentially reflects heat flow through regions having the greatest conductivity (i.e., the path of least resistance) and not heat flow through all parts of the waste.

Btu value, specific heat, and ash content were also considered for predicting heat transfer characteristics. These parameters can no better account for non-homogeneity than thermal conductivity; additionally, they are not directly related to heat transfer characteristics. Therefore, these parameters do not provide a better indication of heat transfer that will occur in any specific waste.

(2) Boiling Point. Once heat is transferred to a constituent within a waste, then removal of this constituent from the waste will depend on its volatility. As a surrogate of volatility, EPA is using boiling point of the constituent. Compounds with lower boiling points have higher vapor pressures and, therefore, would be more likely to vaporize. The Agency recognizes that this parameter does not take into consideration the impact of other compounds in the waste on the boiling point of a constituent in a mixture; however, the Agency is not aware of a better measure of volatility that can easily be determined.

Incineration Design and Operating Parameters

Liquid Injection

For a liquid injection unit, EPA's analysis of whether the unit is well designed will focus on (1) the likelihood that sufficient energy is provided to the waste to overcome the activation level for breaking molecular bonds and (2) whether sufficient oxygen is present to convert the waste constituents to carbon dioxide and water vapor. The specific design parameters that the Agency will evaluate to assess whether these conditions are met are: temperature, excess oxygen, and residence time.

Below is a discussion of why EPA believes these parameters to be important, as well as a discussion of how these parameters will be monitored during operation.

It is important to point out that, relative to the development of land disposed restriction standards, EPA is only concerned with these design parameters when a quench water or scrubber water residual is generated from treatment of a particular waste. If treatment of a particular waste in a liquid injection unit would not generate a wastewater stream, then the Agency, for purposes of land disposal treatment standards, would only be concerned with the waste characteristics that affect selection of the unit, not the above-mentioned design parameters.

(1) Temperature. Temperature is important in that it provides an indirect measure of the energy available (i.e., Btus/hr) to overcome the activation energy of waste constituents. As the design temperature increases, the more likely it is that the molecular bonds will be destabilized and the reaction completed.

The temperature is normally controlled automatically through the use of instrumentation which senses the temperature and automatically adjusts the amount of fuel and/or waste being fed. The temperature signal transmitted to the controller can be simultaneously transmitted to a recording device, referred to as a strip chart, and thereby continuously recorded. To fully assess the operation of the unit, it is important to know not only the exact location in the incinerator that the temperature is being monitored but also the location of the design temperature.

(2) Excess Oxygen. It is important that the incinerator contain oxygen in excess of the stiochiometric amount necessary to convert the organic compounds to carbon dioxide and water vapor. If insufficient oxygen is present, then destabilized waste constituents could recombine to the same or other BDAT list organic compounds and potentially cause the scrubber water to contain higher concentrations of BDAT list constituents than would be the case for a well operated unit.

In practice, the amount of oxygen fed to the incinerator is controlled by continuous sampling and analysis of the stack gas. If the amount of oxygen drops below the design value, then the analyzer transmits a signal to the valve controlling the air supply and thereby increases the flow of oxygen to the afterburner. The analyzer simultaneously transmits a signal to a recording device so that the amount of excess oxygen can be continuously recorded. Again, as with temperature, it is important to know the location from which the combustion gas is being sampled.

(3) Carbon Monoxide. Carbon monoxide is an important operating parameter because it provides an indication of the extent to which the waste organic constituents are being converted to CO_2 and water vapor. As the carbon monoxide level increases, it indicates that greater amounts of organic waste constituents are unreacted or partially reacted. Increased carbon monoxide levels can result from insufficient excess oxygen, insufficient turbulence in the combustion zone, or insufficient residence time.

(4) Waste Feed Rate. The waste feed rate is important to monitor because it is correlated to the residence time. The residence time is associated with a specific Btu energy value of the feed and a specific volume of combustion gas generated. Prior to incineration, the Btu value of the waste is determined through the use of a laboratory device known as a bomb calorimeter. The volume of combustion gas generated from the waste to be incinerated is determined from an analysis referred to as an ultimate analysis. This analysis determines the amount of elemental constituents present which include carbon, hydrogen, sulfur, oxygen, nitrogen, and halogens. Using this analysis plus the total amount of air added, the volume of combustion gas can be calculated. Having determined both the Btu content and the expected combustion gas volume, the feed rate can be fixed at the desired residence time. Continuous monitoring of the feed rate will determine whether the unit was operated at a rate corresponding to the designed residence time.

Rotary Kiln

For this incineration, EPA will examine both the primary and secondary chamber in evaluating the design of a particular incinerator. Relative to the primary chamber, EPA's assessment of design will focus on whether it is likely that sufficient energy will be provided to the waste in order to volatilize the waste constituents. For the secondary chamber, analogous to the sole liquid injection incineration chamber, EPA will examine the same parameters discussed previously under liquid injection incineration. These parameters will not be discussed again here.

The particular design parameters to be evaluated for the primary chamber are: kiln temperature, residence time, and revolutions per minute. Below is a discussion of why EPA believes these parameters to be important, as well as a discussion of how these parameters will be monitored during operation.

(1) Temperature. The primary chamber temperature is important, in that it provides an indirect measure of the energy input (i.e., BTUs/hr) that is available for heating the waste. The higher the temperature is designed to be in a given kiln, the more likely it is that the constituents will volatilize. As discussed earlier under "Liquid Injection", temperature should be continuously monitored and recorded. Additionally, it is important to know the location of the temperature sensing device in the kiln.

(2) Residence Time. This parameter is important in that it affects whether sufficient heat is transferred to a particular constituent in order for volatilization to occur. As the time that the waste is in the kiln is increased, a greater quantity of heat is transferred to the hazardous waste constituents. The residence time will be a function of the specific configuration of the rotary kiln including the length and diameter of the kiln, the waste feed rate, and the rate of rotation.

(3) Revolutions Per Minute (RPM). This parameter provides an indication of the turbulence that occurs in the primary chamber of a rotary kiln. As the turbulence increases, the quantity of heat transferred to the waste would also be expected to increase. However, as

the RPM value increases, the residence time decreases resulting in a reduction of the quantity of heat transferred to the waste. This parameter needs to be carefully evaluated because it provides a balance between turbulence and residence time.

Fluidized Bed

As discussed previously, in the section on "Underlying Principles of Operation", the primary chamber accounts for almost all of the conversion of organic wastes to carbon dioxide, water vapor, and acid gas if halogens are present. The secondary chamber will generally provide additional residence time for thermal oxidation of the waste constituents. Relative to the primary chamber, the parameters that the Agency will examine in assessing the effectiveness of the design are temperature, residence time, and bed pressure differential. The first two were discussed under rotary kiln and will not be discussed here. The latter, bed pressure differential, is important in that it provides an indication of the amount of turbulence and, therefore, indirectly the amount of heat supplied to the waste. In general, as the pressure drop increases, both the turbulence and heat supplied increase. The pressure drop through the bed should be continuously monitored and recorded to ensure that the designed valued is achieved.

Fixed Hearth

The design considerations for this incineration unit are similar to a rotary kiln with the exception that rate of rotation (i.e., RPMs) is not an applicable design parameter. For the primary chamber of this unit, the parameters that the Agency will examine in assessing how well the unit is designed are the same as discussed under rotary kiln; for the secondary chamber (i.e., afterburner), the design and operating parameters of concern are the same as previously discussed under "Liquid Injection".

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V. REFERENCES

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The comparative method of measuring thermal conductivity has been proposed as an ASTM test method under the name "Guarded, Comparative, Longitudinal Heat Flow Technique". A thermal heat flow circuit is used which is the analog of an electrical circuit with resistances in series. A reference material is chosen to have a thermal conductivity close to that estimated for the sample. Reference standards (also known as heat meters) having the same cross-sectional dimensions as the sample are placed above and below the sample. An upper heater, a lower heater, and a heat sink are added to the "stack" to complete the heat flow circuit. See Figure 1.

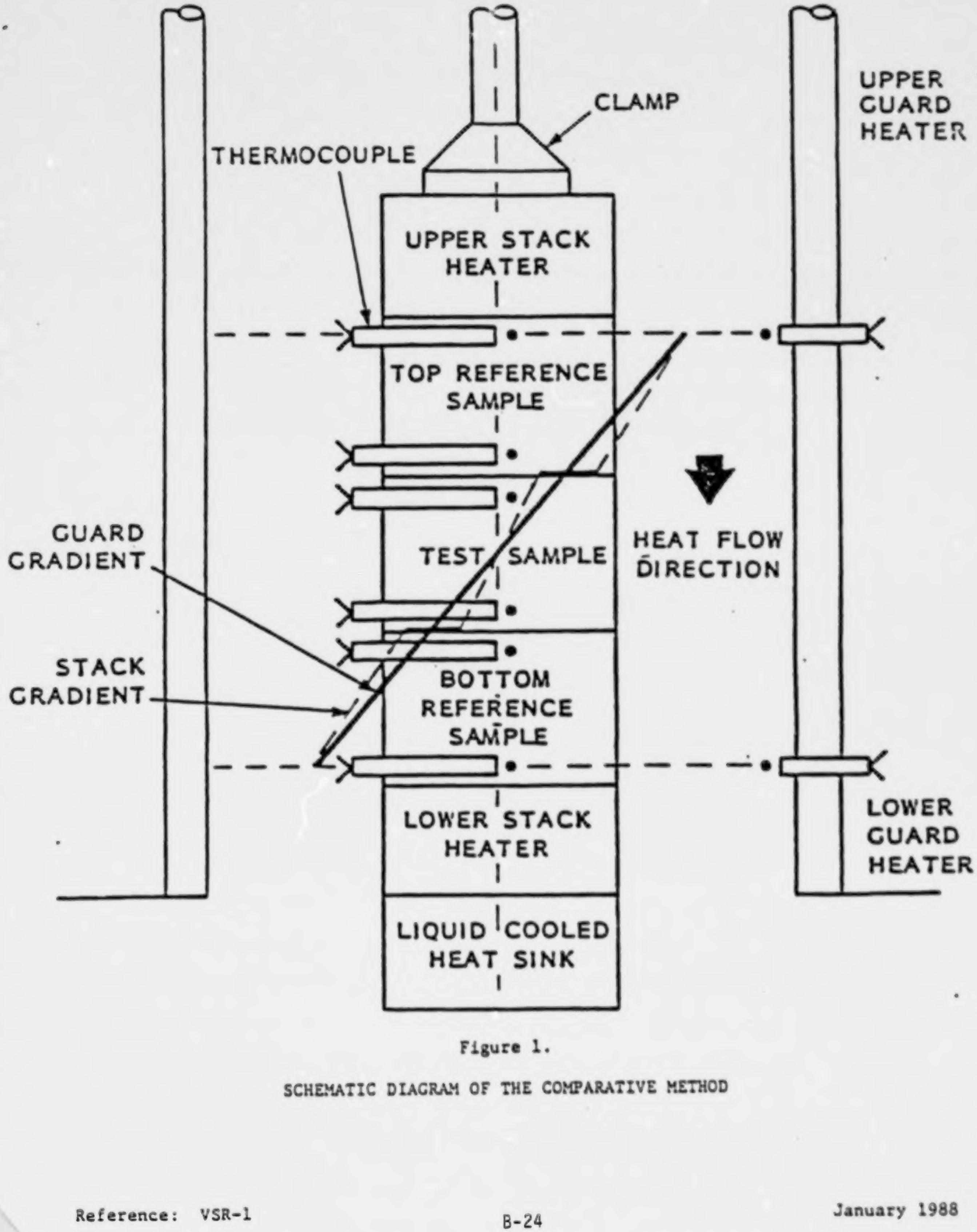
CLAMP
UPPER GUARD HEATER
THERMOCOUPLE
UPPER STACK HEATER
TOP REFERENCE SAMPLE
TEST SAMPLE
HEAT FLOW DIRECTION
GUARD GRADIENT
STACK GRADIENT
BOTTOM REFERENCE SAMPLE
LOWER STACK HEATER
LOWER GUARD HEATER
LIQUID COOLED HEAT SINK

Figure 1.

SCHEMATIC DIAGRAM OF THE COMPARATIVE METHOD

The temperature gradients (analogous to potential differences) along the stack are measured with type K (chromel/alumel) thermocouples placed at known separations. The thermocouples are placed into holes or grooves in the references and also in the sample whenever the sample is thick enough to accommodate them.

For molten samples, pastes, greases, and other materials that must be contained, the material is placed into a cell consisting of a top and bottom of Pyrex 7740 and a containment ring of marinite. The sample is 2 inch in diameter and .5 inch thick. Thermocouples are not placed into the sample but rather the temperatures measured in the Pyrex are extrapolated to give the temperature at the top and bottom surfaces of the sample material. The Pyrex disks also serve as the thermal conductivity reference material.

The stack is clamped with a reproducible load to insure intimate contact between the components. In order to produce a linear flow of heat down the stack and reduce the amount of heat that flows radially, a guard tube is placed around the stack and the intervening space is filled with insulating grains or powder. The temperature gradient in the guard is matched to that in the stack to further reduce radial heat flow.

The comparative method is a steady state method of measuring thermal conductivity. When equilibrium is reached the heat flux (analogous to current flow) down the stack can be determined from the references. The heat into the sample is given by

$$Q_{in} = \lambda_{top}(dT/dx)_{top}$$

and the heat out of the sample is given by

$$Q_{out} = \lambda_{bottom}(dT/dx)_{bottom}$$

where

λ = thermal conductivity

dT/dx = temperature gradient

and top refers to the upper reference while bottom refers to the lower reference. If the heat was confined to flow just down the stack, then Q_{in} and Q_{out} would be equal. If Q_{in} and Q_{out} are in reasonable agreement, the average heat flow is calculated from

$$Q = (Q_{in} + Q_{out})/2$$

The sample thermal conductivity is then found from

$$\lambda_{sample} = Q/(dT/dx)_{sample}$$

The result for the K102 Activated Charcoal Waste tested here is given in Table 1. The sample was held at an average temperature of 42C with a 53C temperature drop across the sample for approximately 20 hours before the temperature profile became steady and the conductivity measured. At the conclusion of the test it appeared that some "drying" of the sample had occurred.

APPENDIX C

WET AIR OXIDATION

This Appendix, consisting of a description of the wet air oxidation treatment technology, includes information relevant to the use and understanding of the background document for the K011, K013, and K014 listed hazardous wastes subject to the RCRA "Land Ban" restrictions.

It is anticipated that non-substantive changes will be made to this treatment technology description prior to publication of final "Second Thirds" Land Ban regulations. These changes will be primarily formatting and organizational in nature.

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APPENDIX C

Technology - Wet Air Oxidation

(1) Applicability

The wet air oxidation process, the aqueous phase oxidation of dissolved or suspended organic substances or other hazardous compounds at elevated temperatures and pressures, has been developed and commercialized within the past 15 years, primarily as a less expensive alternative to other types of chemical oxidation processes.

Wet air oxidation is used to treat aqueous wastes that contain certain BDAT list organics and oxidizable inorganics such as cyanide. The process has typically been used to oxidize sewage sludge, regenerate spent activated carbon, and treat process wastewaters. Wastewaters treated include pesticide wastes, petrochemical process wastes, cyanide-containing metal finishing wastes, spent caustic wastewaters containing phenolic compounds, and some organic chemical production wastewaters.

This technology differs from the treatment technologies generally used to treat wastewaters containing organics in several aspects. First, wet air oxidation can be used to treat wastewaters that have higher organic concentrations than are normally handled by biological treatment or carbon adsorption but may be too dilute to be effectively treated by thermal processes such as incineration. Wet air oxidation is most applicable for waste streams containing dissolved or suspended organics in the 500 to 15,000 mg/l range, although more concentrated wastes can be treated if they are first diluted with water. Below 500 mg/l, the rates of wet oxidation of most organic constituents are too slow for efficient application of this technology. For these low-concentration wastes, those technologies applicable to treatment of more dilute waste streams, such as biological treatment or carbon adsorption, may be selected instead of wet air oxidation.

Second, wet air oxidation can be applied to wastes that have significant concentrations of metals (roughly 2 percent), whereas carbon adsorption, biological treatment, and other forms of chemical oxidation may experience difficulties in treating such wastes.

It is important to point out that wet air oxidation proceeds by a series of reaction steps and the intermediate products formed are not always as readily oxidized as are the original constituents; therefore, the process does not always achieve complete oxidation of the organic constituents. Accordingly, in applying this technology it is important to assess potential products of incomplete oxidation to determine whether further treatment is necessary or whether this technology is appropriate at all.

Studies of the wet air oxidation of different compounds have led to the following empirical observations concerning a compound's susceptibility to wet air oxidation based on its chemical structure:

a. Aliphatic compounds, even with multiple halogen atoms, can be destroyed within conventional wet oxidation conditions. Oxygenated compounds (such as low molecular weight alcohols, aldehydes, ketones, and carboxylic acids) form, but these compounds are readily biotreatable.

b. Aromatic hydrocarbons, such as toluene, acenaphthene, or pyrene, are easily oxidized.

c. Halogenated aromatic compounds can be oxidized provided there is at least one nonhalogen functional group present on the ring (i.e., pentachlorophenol (-OH) or 2,4,6-trichloroaniline ($-NH_2$)).

d. Halogenated aromatic compounds, such as 1,2-dichlorobenzene, and PCBs, such as Aroclor 1254, are resistant to wet air oxidation under conventional conditions.

e. Halogenated ring compounds, such as the pesticides aldrin, dieldrin, and endrin, are expected to be resistant to conventional wet air oxidation.

f. DDT, although destroyed, results in the formation of intractable oils in conventional wet air oxidation.

g. In heterocyclic compounds containing oxygen, nitrogen, or sulfur, the O, N, or S atoms provide a point of attack for oxidation; thus these compounds are expected to be destroyed by wet air oxidation.

(2) Underlying Principles of Operation

The wet air oxidation of aqueous wastes is accomplished at high temperatures and pressures. The typical operating range of temperature for the treatment process is 175°325°C. The pressure must be maintained at a level high enough to prevent excessive evaporation of the liquid phase at these temperatures, generally between 300 and 3000 psi. At these elevated temperatures and pressures, the solubility of oxygen in water is dramatically increased, thus providing a strong driving force for the oxidation. The reaction must take place in the aqueous phase because the chemical reactions involve both oxygen (oxidation) and water (hydrolysis). The wet air oxidation process for a specific organic compound generally involves a number of oxidation and hydrolysis reactions in series, which degrade the initial compound by steps into a series of compounds of simpler structure ending with carbon dioxide, water, and other very simple organic compounds. Complete wet air oxidation results in the conversion of hazardous compounds completely into carbon dioxide, water vapor, ammonia (in the case of nitrogen-containing wastes), sulfate (in the case of sulfur-containing wastes), and halogen acids (in the case of halogenated wastes).

The amount of information available is not sufficient to unequivocally determine the reaction mechanism or the reaction rates for individual process steps. However, it is reasonable to assume that at least trace quantities of partial degradation products will remain in the treated wastewaters. For this reason, effluents from wet air oxidation processes may be given subsequent treatment, such as chemical oxidation, biological treatment, or carbon absorption, before being discharged.

(3) Description of Wet Air Oxidation Process

A conventional wet air oxidation system consists of a high-pressure liquid feed pump, an oxygen source (air compressor or liquid oxygen vaporizer), a reactor, heat exchangers, a vapor-liquid separator, and process regulators. A basic flow diagram is shown in Figure 1.

Generally, batch wet air oxidation operates as follows. First, a copper catalyst solution may be mixed with the aqueous waste stream if preliminary testing indicates that a catalyst is necessary. The waste is then pumped into the reaction chamber. The aqueous waste is pressurized and heated to a prespecified temperature. After reaction conditions have been established, air is fed to the reactor for the duration of the

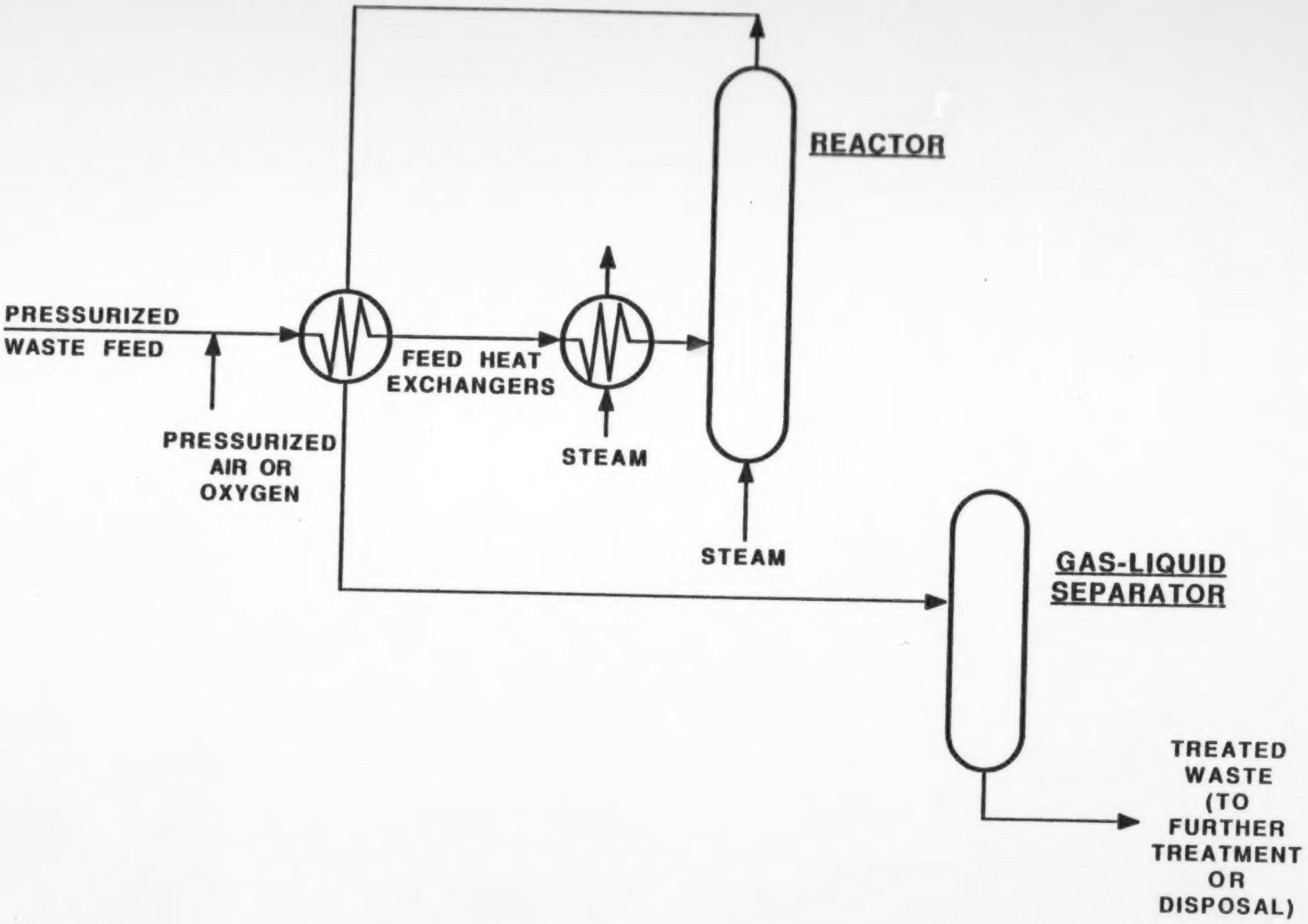
PRESSURIZED
WASTE FEED
PRESSURIZED
AIR OR
OXYGEN
FEED HEAT
EXCHANGERS
STEAM
REACTOR
STEAM
GAS-LIQUID
SEPARATOR
TREATED
WASTE
(TO
FURTHER
TREATMENT
OR
DISPOSAL)

FIGURE 1 WET AIR OXIDATION PROCESS FLOW DIAGRAM.

design reaction time. At the completion of the wet air oxidation process, suspended solids or gases are removed and the remaining treated aqueous waste is either discharged directly or fed to a secondary treatment system, such as a biological treatment unit, if further processing is necessary prior to discharge.

Wet air oxidation can also be operated as a continuous process. In continuous operation, the hot reactor effluent is used to preheat the influent waste stream. The waste is then pressurized, mixed with air, and fed to the reactor. Waste feed flow rate controls the reactor residence time.

(4) Waste Characteristics Affecting Performance (WCAPs)

In determining whether performance standards can be transferred to an untested waste from a previously tested waste, EPA will examine the following waste characteristics: (a) chemical oxygen demand and (b) the presence of interfering substances.

(a) Chemical oxygen demand. The chemical oxygen demand (COD) of the waste is a measure of the oxygen required for complete oxidation of the oxidizable waste constituents. There is a physical limit to the amount of oxygen that can be supplied to the waste that is based on the solubility of oxygen and the rate of dissolution of oxygen from the gas phase to the liquid phase. This sets an upper limit on the amount of oxidizable compounds that can be treated by wet air oxidation. Thus, high-COD wastes may require dilution for effective treatment to occur.

(b) Presence of interfering substances. In some cases, addition of a water-soluble copper salt catalyst to the waste before processing is necessary for efficient oxidation treatment (for example, for oxidation of some halogenated organics). Other metals have been tested and have been found to be less effective. Interfering substances for the wet air oxidation process are essentially those that cause the formation of insoluble copper salts when copper catalysts are being used. To be effective, the copper ions must be dissolved in solution. Sulfide, carbonate, and other negative ions that form insoluble copper salts may interfere with treatment effectiveness if present in significant amounts in wastes for which catalysts are necessary for effective treatment. If an untested waste for which a catalyst is necessary has a signficantly higher concentration of sulfide, carbonate, or other anion that forms an insoluble salt than the tested waste, then treatment performance may not be transferable to that waste.

(5) Design and Operating Parameters

EPA's analysis of whether a wet air oxidation treatment unit is well designed and well operated will focus on the following parameters: (a) temperature, (b) residence time, (c) excess oxygen concentration, (d) pressure, and (e) addition of catalyst.

(a) Temperature. Temperature is the most important parameter affecting the system. The design temperature must be high enough to allow the oxidation reactions to proceed at acceptable rates. Raising the temperature increases the wet air oxidation rate by enhancing oxygen solubility and oxygen diffusivity. The process is normally operated in the temperature range of 175-325°C, depending on the hazardous constituent(s) to be treated. EPA will monitor the reactor temperature during oxidation to ensure that the design temperature is maintained.

(b) Residence time. Residence time is important in ensuring that the wastes are in the reactor long enough for the oxidation reaction to reach completion. In a continuous system, the size of the reactor and the waste flow rate determine residence time. Typically, the reaction rates are relatively fast for the first 30 minutes; after 60 minutes, the rates become slow. Typical residence times, therefore, are approximately 1 hour or slightly longer. EPA will monitor the reaction time for batch processes and the waste feed flow rate for continuous processes.

(c) Excess oxygen concentration. The system must be designed to supply adequate amounts of oxygen for the compounds to be oxidized. An estimate of the amount of oxygen needed can be made based on the COD content of the untreated waste; excess oxygen should be supplied to ensure complete oxidation. The source of oxygen is compressed air or a high-pressure pure oxygen stream. The excess oxygen concentration (the concentration of oxygen in the gas leaving the reactor) can be continuously monitored by sampling of the vent gas to ensure that an adequate amount of oxygen or air is being supplied.

(d) Pressure. The design pressure must be high enough to prevent excessive evaporation of water at the specified reactor temperature; this condition allows the oxidation reaction to occur in the aqueous phase, thereby improving treatment effectiveness. Continuous pressure monitoring and recording help ensure that the treatment system is operating at design conditions. As with temperature, the Agency will monitor the pressure during a treatment test to ensure that proper design conditions are maintained during treatment.

(e) Addition of catalyst. Adding a catalyst that promotes oxygen transfer and thus enhances oxidation has the effect of lowering the necessary reactor temperature and/or improving the level of destruction of oxidizable compounds. For waste constituents that are more difficult to oxidize, catalyst addition may be necessary to effectively destroy the constituent of concern. Catalysts typically used for this purpose include copper bromide and copper nitrate. If a catalyst is required, EPA will monitor the type, quantity, and method of addition of the catalyst.

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APPENDIX D

CRITICAL FLUID EXTRACTION

This Appendix, consisting of a description of the critical fluid extraction treatment technology, includes information relevant to the use and understanding of the background document for the K011, K013, and K014 listed hazardous wastes subject to the RCRA "Land Ban" restrictions.

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APPENDIX D

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Technology - Critical Fluid Extraction

(1) Applicability

Critical fluid extraction is a comparatively new technology. It is applicable to wastes containing a variety of relatively high molecular weight organic hazardous components that are soluble in pressurized, relatively low molecular weight fluids such as ethylene, carbon dioxide, or propane. Compounds that have been extracted from wastes by this process include aliphatic hydrocarbons, alkenes, simple aromatic solvents such as benzene and toluene, polynuclear aromatics, and phenols. In theory, this process should also be applicable to a variety of other organic waste constituents. Critical fluid extraction has been demonstrated for treatment of API separator sludges and other hydrocarbon-bearing wastes generated by the petroleum and petrochemicals industries. It may also be applicable to wastes of similar composition generated by other industries such as the organic chemicals industry.

(2) Underlying Principles of Operation

Critical fluid extraction is a technology that takes advantage of the enhanced solubilities of various organic compounds in hydrocarbons and other solvents in the critical state (i.e., low temperature and high pressure). The solvents used are compounds that are usually gases at ambient conditions. The volatile organic solvent is pressurized, which converts it from a gas to a liquid. As a liquid, it leaches (dissolves) the organic constituents out of the complex waste with which it is mixed.

(3) Description of the Critical Fluids Extraction Process

Oil refinery sludges or other organic wastes are first blended together in a blending tank and mixed well to yield a homogeneous, pumpable mixture. This mixture is then pumped to an extraction vessel filled with a liquified gas such as carbon dioxide, propane, butane, or pentane and is mixed under pressure to extract (dissolve) hydrocarbon components from the waste into the liquified gas solvent. After the hydrocarbon components of the waste dissolve in the pressurized liquid, the resulting solution is gravity-separated into a wastewater stream and a solvent-rich stream. The wastewater stream, containing inorganic solids, is sometimes filtered under pressure to remove the insoluble components. The solvent-rich stream is fed to a pressurized evaporation unit. The solvent (carbon dioxide, propane, butane, or pentane) is evaporated by dropping the pressure and is subsequently recovered, repressurized, and recondensed for reuse. The residue from the evaporation, consisting of a liquid hydrocarbon mixture, is then returned to the refinery or other process plant for reprocessing and/or reuse, blended with fuels for heat recovery, or incinerated.

The inorganic residuals filtered from the waste/solvent mixture are either land disposed (if they contain nontreatable levels of hazardous constituents such as certain metals (e.g., chromium, lead)) or further treated by processes such as stabilization prior to land disposal.

(4) Waste Characteristics Affecting Performance (WCAPs)

In determining whether performance standards can be transferred to an untested waste from a previously tested waste, EPA will focus on the following waste characteristics: (a) concentration of extractable hydrocarbons and (b) alkalinity concentration/pH.

(a) Concentration of extractable hydrocarbons. The process is designed to extract hydrocarbon components from mixed oily and organic waste liquids and sludges. For this process to be economically applied, the waste should contain at least a few percent by weight of extractable hydrocarbons. The process has been demonstrated on wastes containing from 5 to 34 percent hydrocarbons. For lower concentrations, batch distillation or conventional solvent extraction may be more economical. Also, critical fluid extraction is not useful for wastes containing high concentrations of extractable hydrocarbons (higher than 95 percent). These wastes are more amenable to fractionation treatment. Total extractable hydrocarbon content can be estimated by measurement of the total organic carbon (TOC) content. If the TOC of an untested waste is significantly higher than that of the tested waste, then EPA will consider the use of other, more applicable treatment technologies for the untested waste.

(b) Alkalinity concentration/pH. When carbon dioxide is used as the extraction fluid, high alkalinity will interfere with the process because carbon dioxide will react to form carbonates and bicarbonates. This will result in excessive carbon dioxide consumption. Alkalinity is a function of pH. For wastes having high pH or alkalinity levels, an extraction fluid other than carbon dioxide should be used. The same problem does not arise if a hydrocarbon fluid (propane, butane, etc.) is used. Both alkalinity and pH can be measured by conventional analytical techniques. If carbon dioxide was the extraction fluid used on a tested waste and the alkanity or pH level of the untested waste is significantly higher than that of the tested waste, then EPA will consider the use of other, more applicable treatment technologies for the untested waste.

(5) Design and Operating Parameters

EPA will examine several design and operating parameters to determine whether a critical fluid extraction unit is properly designed and operated. The design and operating parameters of concern are (a) operating pressure, (b) degree of initial waste mixing, (c) degree of mixing during extraction, and (d) operating temperature.

(a) Operating pressure. Critical fluid extraction systems operate at pressures at which the critical fluids will be liquids at ambient temperatures. Pressure is normally monitored by means of gauges and recorders attached to the extraction vessel. EPA will monitor the extraction vessel pressure to determine whether the system is operating at or near the design value.

(b) Degree of initial waste mixing. The waste must be premixed before introduction into the extraction system to ensure a uniform, pumpable blend of material. The waste is normally mixed in tanks or other vessels. Any well-designed and well-operated system should have such waste-blending equipment as part of the treatment train.

(c) Degree of mixing during extraction. During the fluid extraction, the solvent and waste need to be mixed to ensure maximum contact and, hence, efficiency of extraction. Any well-designed system should include a pressurized extraction vessel that is equipped with an operable mixing system.

(d) Temperature. The process is normally operated at ambient temperature, although it is possible to use higher temperatures when necessary. In all cases, temperatures used must be below the critical temperature of the solvent used to ensure that the solvent is present in the extraction vessel in the liquid phase*. EPA monitors the extraction vessel temperature to ensure that the system is well operated.

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*The critical temperature of a substance is that temperature above which the substance cannot be liquified, no matter how high the operating pressures.

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APPENDIX E

AEROBIC BIOLOGICAL TREATMENT

This Appendix, consisting of a description of the aerobic biological treatment technology, includes information relevant to the use and understanding of the background document for the K011, K013, and K014 listed hazardous wastes subject to the RCRA "Land Ban" restrictions.

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APPENDIX E

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Technology - Aerobic Biological Treatment

Biological treatment is a technology that uses living microorganisms to decompose organic constituents. Biological treatment can occur either in the presence of oxygen, known as aerobic treatment, or in the absence of oxygen, referred to as anaerobic treatment. This technology has been employed both where the organics are contained in wastes comprised principally of water and where the wastes have a high filterable solids content such as contaminated soils. This technology discussion addresses the common form of biological treatment, aerobic treatment of wastewaters. Other biological treatment systems are discussed separately.

1.1 Applicability

Relative to treatment of wastewaters containing BDAT list organic constituents, the parameters that affect selection of aerobic biological treatment are biochemical oxygen demand (BOD) and total organic carbon (TOC). Both parameters are needed to assess the extent to which the organic constituents present are degradable. If the TOC value is significantly larger than the BOD value, then it is likely that the BDAT list organics or other organics present are not degradable or that constituents, such as heavy metals, are present at toxic concentrations. If this is the case, another technology should be evaluated.

1.2 Underlying Principles of Operation

Aerobic processes use microorganisms that require oxygen (as air or oxygen-containing compounds) for biodegradation of organic constituents. In addition, nutrients are needed in the form of nitrogen and phosphorus.

The aerobic biodegradation process can be represented by the following generic equation:

$$C_x H_y + O_2 \xrightarrow[\text{nutrients}]{\text{Microorganisms}} H_2O + CO_2 + \text{cellular biomass.}$$

The aerobic bacteria degrade the organic waste to obtain energy for cell metabolism and cell growth. A fraction of the waste is also oxidized to form products such as nitrates (NO_3), sulfates (SO_4), water (H_2O), and carbon dioxide (CO_2).

Biological oxidization of wastewaters containing organic constituents will result in the net accumulation of a biomass of expired microorganisms consisting mainly of cell protein. However, the cellular biomass or sludges may also contain entrained constituents of the wastewater, partially degraded constituents, or intermediate products that have not been degraded. If biological treatment is carried out in an unlined impoundment or lagoon with no drain collection system, such as aerated lagoons, any underlying soil materials may be contaminated by leachate from the overlying sludges or the wastewater itself.

Biological oxidization sludges must be periodically removed (or wasted) in order to maintain proper operation of the wastewater treatment system. Waste biological sludges may be routed to a clarification tank where they are allowed to settle. Settled sludges may be further dewatered on sludge drying beds or by mechanical dewatering. The final dewatered, settled waste sludge is a residual that must be disposed of.

1.3 Description of Biological Treatment

There are four types of aerobic biological treatment processes:

- Activated sludge,
- Aerated treatment,
- Trickling filters, and
- Rotating biological contactors (RBCs)

1.3.1 Activated Sludge

The activated sludge process is currently the most widely used biological treatment process. This is due in part to the fact that recirculation of the biomass, which is an integral part of the process, allows microorganisms to adapt to changes in wastewater composition by relatively short acclimation processes and also allows a greater degree of control over the acclimated bacterial population.

A schematic diagram of the activated sludge process is shown in Figure 1. Wastewater that contains organic contaminants enters a basin or tank where an aerobic bacterial population is maintained in suspension and aeration is provided. The contents of the basin are referred to as the mixed liquor.

Oxygen is supplied to the aeration basin by mechanical or diffused aeration. A portion of the mixed liquor is continuously discharged from the aeration basin into a clarifier, where the biomass is separated from the treated wastewater by sedimentation. A portion of the biomass is recycled to the aeration basin in order to maintain an optimum concentration of acclimated microorganisms in the aeration basin. The remainder of the separated biomass is discharged or "wasted" and the clarified effluent is discharged. The recycled biomass is referred to as

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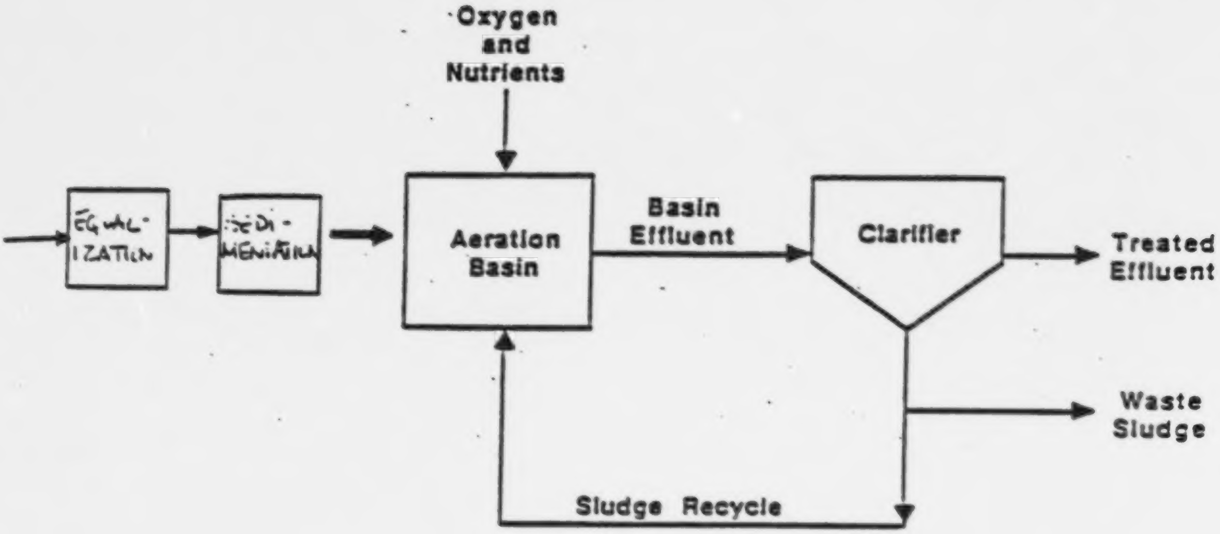
EQUAL-IZATION
SEDI-MENTATION
Oxygen and Nutrients
Aeration Basin
Basin Effluent
Clarifier
Treated Effluent
Waste Sludge
Sludge Recycle

Figure 1
Activated Sludge

activated sludge. The term "activated" is used because the recycled biomass contains living and acclimated microorganisms that will metabolize and assimilate organic material at a high rate when returned to the aeration basin. This is because of the low food-to-microorganism ratio in the sludge from the clarifier.

An important variation on the activated sludge process is the Powdered Activated Carbon Treatment (PACT) process. This process offers a combined treatment and pretreatment unit in which noncompatible and toxic constituents are adsorbed onto activated carbon, and microorganism compatible waste remains in solution. Powdered activated carbon is added directly to the aeration basin of the activated sludge treatment system. Overall removal efficiency is improved because compounds that are not readily biodegradable or that are toxic to the microorganisms are adsorbed onto the surface of the powdered activated carbon. The carbon is removed from the wastewater in the final clarifier along with the biological sludge. Both the carbon and the biological sludge must be treated further or disposed of. Generally, the activated carbon is recovered, regenerated, and recycled.

1.3.2 Aerated Treatment

Aerated treatment occurs in a large pond or tank that is equipped with mechanical aerators to maintain an aerobic environment and to avoid settling of the suspended biomass. In the beginning, the population of microorganisms in aerated treatment is much lower than in an activated sludge system because there is no sludge recycle. A significantly longer residence time is therefore required in order to achieve a specified effluent quality. However, this longer residence time may be an advantage when complex organic chemicals are to be degraded. Biodegradation of the organic contaminants in the wastewater occurs throughout the system. The effluent from the system may flow to a secondary sedimentation unit for removal of suspended solids. Alternatively, the mechanical aerators may be shut off in the system for a period of time to facilitate settling and sedimentation prior to discharge of the effluent.

1.3.3 Trickling Filters

The trickling filter biological treatment process involves contact between wastewater containing organic contaminants and a population of microorganisms that is fixed or attached to the surface of the filter media. Rocks or synthetic material such as plastic rings and saddles are typically used as filter media. The wastewater is distributed over the top of the filter by a rotating distribution arm or a fixed distributor system. Wastewater forms a thin layer as it flows downward through the filter and over the microorganism layer on the surface of the media. As the distribution arm rotates, the microorganism layer is alternately exposed to a flow of wastewater and air. In the fixed distributor system, the wastewater flow is cycled on and off at a specified dosing rate to ensure that an adequate supply of oxygen is available to the microorganisms. A schematic diagram of a trickling filter is shown in Figure 2.

Trickling filter systems are typically used as a roughing filter to reduce the organic loading on a downstream activated sludge process.

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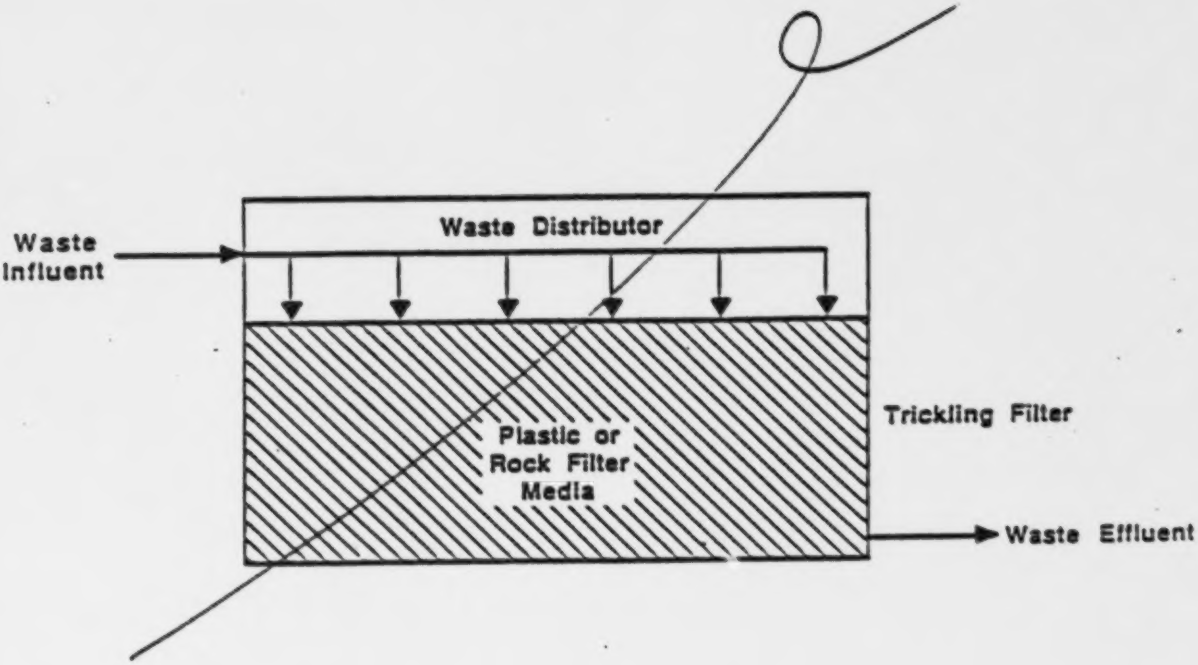
Waste Distributor
Waste Influent
Trickling Filter
Plastic or Rock Filter Media
Waste Effluent

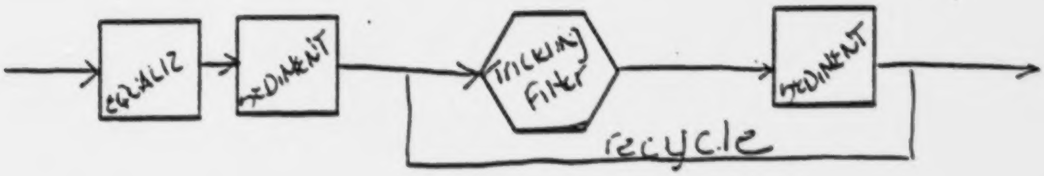
EQUALIZ
SEDIMENT
Trickling Filter
SEDIMENT
recycle

Figure 2
Trickling Filter

Trickling filters can be used for the treatment of wastewaters that could potentially produce "bulking" sludge (i.e., a sludge with poor settling characteristics and poor compactibility in an activated sludge process), because the microbial film that sloughs off the trickling filter is relatively dense and can be readily removed by sedimentation.

1.3.4 Rotating Biological Contactors

The rotating biological contactor (RBC) consists of a series of closely spaced, parallel disks that are rotated while partially immersed in a trough of wastewater. The disks are constructed of polystyrene, polyvinyl chloride, or similar materials. Rotating biological contactors can be customized depending on the type of influent waste requiring biodegradation. Each disk is covered with a biological slime that degrades dissolved organic matter present in the wastewater. The rotation of the disk facilitates exposure of microorganisms to the air. As the disk is rotated out of the tank, it carries a film of the wastewater into the air where the oxygen is available for aerobic biological decomposition. As excess biomass is produced, it sloughs off the disk and is separated from the process effluent in a final clarifier. The sloughing off process is similar to what occurs in a trickling filter, which was described above. A schematic diagram of a rotating biological contactor is shown in Figure 3.

1.4 Waste Characteristics Affecting Performance

In determining whether treatment performance for a previously tested waste can be transferred to an untested waste, EPA will examine waste characteristics that either inhibit the ability of the microorganism to

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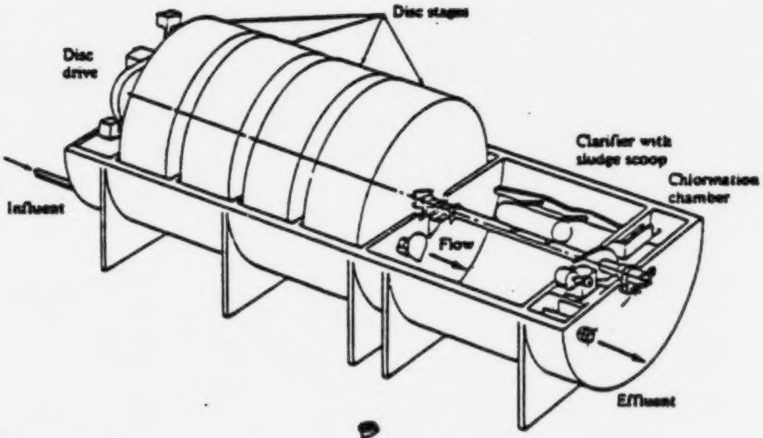
Disc stages
Disc drive
Clarifier with sludge scoop
Chlorination chamber
Influent
Flow
Effluent

Figure 3

ROTATING BIOLOGICAL CONTACTOR

SOURCE: CLARK & VIESSMAN 1977

degrade the organic constituents of concern or are toxic to the microorganisms. Such waste characteristics include: (1) type and concentration of organic constituents, (2) surfactants, and (3) toxic constituents. Each of these characteristics is discussed below.

1.4.1 Type and Concentration of Organic Constituents

Because the organic compounds in the waste effectively serve as a feed supply for the microorganism, it is important that a significant quantity of the organics in the waste is degradable. If this is not the case (i.e., a significant fraction of the organic constituents is refractory), then it will be difficult for the microorganisms to successfully acclimate to the waste and achieve effective treatment. EPA recognizes that it is difficult to quantify the total concentration of refractory organic constituents. EPA will, however, review the type of concentration of BDAT list constituents present and assess whether any of these constituents can adversely affect treatment performance. In addition, EPA will also evaluate any data or information on non-BDAT list organics that would assist in determining the quantity of non-BDAT refractory compounds, as well as the potential for reducing treatment effectiveness.

1.4.2 Surfactants

The term "surfactant" is an abbreviation for surface active agent. Surface active agents are compounds that allow solutions to perform multiple operations because the compound contains molecules that have opposite solubility tendencies (e.g., an oil soluble and a water soluble group).

Surfactants can affect biological treatment performance by forming a film on the organic constituent of concern, thereby establishing a barrier to oxygen transfer. As discussed in the "Underlying Principles of Operation," oxygen is an integral part of aerobic biological treatment.

EPA believes that the best method available to measure the quantity of surfactants is Method 512 (Surfactants) contained in Standard Methods for the Examination of Water and Wastewater, Sixteenth Edition.

1.4.3 Toxic Constituents

A number of constituents and constituent parameters have been identified as potentially toxic to microorganisms. For most of these constituents and constituent parameters, specific concentrations have not been determined. Additionally, defining potential impacts is further complicated by the fact that the degree to which constituents are toxic will also depend on the overall characteristics of the wastes in which they are contained. The characteristics reported in the literature as potentially toxic are metals, total dissolved solids, oil and grease (petroleum based, not of animal or vegetable origin), ammonia, and phenols. It is important to note that the latter two constituents present no problem to the microorganisms at low concentrations. To the extent possible, EPA will analyze for all of the above constituents and/or constituent parameters in assessing performance transfer. For metals, EPA will generally examine only BDAT list metals.

1.5.5 Food-to-Microorganism Ratio (F/M)

This ratio applies only to activated sludge systems and is a measure of the amount of biomass available to metabolize the influent organic loading to the aeration basis. The F/M ratio can be determined by dividing the influent BOD concentration by the concentration of active biomass (MLVSS). It is controlled by adjusting the waste feed rate or the sludge recycle rate. EPA would want information on the design F/M value, as well as the basis for selecting that value. In assessing the operation during treatment, EPA would want periodic analysis of BOD and MLVSS so that the actual F/M ratio could be compared to the design value.

1.5.6 pH and Temperature

In general, neutral or slightly alkaline pH favors bacterial growth. The optimum range for most microorganisms found in biological treatment systems is between 6 and 8. Treatment effectiveness is generally insensitive to changes within this range. However, excursions outside the range can lower treatment performance.

Microbial growth can occur under a wide range of temperatures, although the majority of the microbial species are active between 20 and 35°C. Kinetic rate parameters are sensitive to fluctuations in temperature. The rate of biochemical reactions in cells increases with temperature up to a maximum above which the rate of activity declines as enzyme denaturation occurs and microorganisms either die off or become less active.

Because of the importance of both pH and temperature, EPA would want design specifications for these parameters, as well as conditions during treatment.

1.5.7 Mean Cell Residence Time (MCRT)

In an activated sludge system, the MCRT or sludge age is the length of time organisms are retained in an activated sludge aeration basin before being drawn off as waste sludge. The MCRT must be long enough to allow the organisms in the aeration basis to reproduce. However, in an aerated treatment system there is no sludge recycle and thus the MCRT and the hydraulic retention time are the same. Because of the importance of this parameter EPA would want to know both the design value and the basis for that value. Additionally, EPA would want information on the waste sludge rate so that this value could be determined during treatment.

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APPENDIX F

CHEMICAL PRECIPITATION

This Appendix, consisting of a description of the chemical precipitation treatment technology, includes information relevant to the use and understanding of the background document for the K011, K013, and K014 listed hazardous wastes subject to the RCRA "Land Ban" restrictions.

It is anticipated that non-substantive changes will be made to this treatment technology description prior to publication of final "Second Thirds" Land Ban regulations. These changes will be primarily formatting and organizational in nature.

APPENDIX F

Technology - Chemical Precipitation

Applicability and Use of Chemical Precipitation

Chemical precipitation is used when dissolved metals are to be removed from solution. This technology can be applied to a wide range of wastewaters containing dissolved BDAT list metals and other metals as well. This treatment process has been practiced widely by industrial facilities since the 1940s.

Underlying Principles of Operation

The underlying principle of chemical precipitation is that metals in wastewater are removed by the addition of a treatment chemical that converts the dissolved metal to a metal precipitate. This precipitate is less soluble than the original metal compound, and therefore settles out of solution, leaving a lower concentration of the metal present in the solution. The principal chemicals used to convert soluble metal compounds to the less soluble forms include: lime ($Ca(OH)_2$), caustic ($NaOH$), sodium sulfide (Na_2S), and, to a lesser extent, soda ash (Na_2CO_3), phosphate, and ferrous sulfide (FeS).

The solubility of a particular compound will depend on the extent to which the electrostatic forces holding the ions of the compound together can be overcome. The solubility will change significantly with temperature; most metal compounds are more soluble as the temperature increases. Additionally, the solubility will be affected by the other constituents present in a waste. As a general rule, nitrates, chlorides, and sulfates are more soluble than hydroxides, sulfides, carbonates, and phosphates.

An important concept related to treatment of the soluble metal compounds is pH. This term provides a measure of the extent to which a solution contains either an excess of hydrogen or hydroxide ions. The pH scale ranges from 0 to 14; with 0 being the most acidic, 14 representing the highest alkalinity or hydroxide ion (OH^-) content, and 7.0 being neutral.

When hydroxide is used, as is often the case, to precipitate the soluble metal compounds, the pH is frequently monitored to ensure that sufficient treatment chemicals are added. It is important to point out that pH is not a good measure of treatment chemical addition for compounds other than hydroxides; when sulfide is used, for example, facilities might use an oxidation-reduction potential meter (ORP) correlation to ensure that sufficient treatment chemical is used.

Following conversion of the relatively soluble metal compounds to metal precipitates, the effectiveness of chemical precipitation is a function of the physical removal, which usually relies on a settling process. A particle of a specific size, shape, and composition will settle at a specific velocity, as described by Stokes' Law. For a batch system, Stokes' law is a good predictor of settling time because the pertinent particle parameters remain essentially constant. Nevertheless, in practice, settling time for a batch system is normally determined by empirical testing. For a continuous system, the theory of settling is complicated by factors such as turbulence, short-circuting, and velocity gradients, increasing the importance of the empirical tests.

Description of the Technology

The equipment and instrumentation required for chemical precipitation varies depending on whether the system is batch or continuous. Both operations are discussed below; a schematic of the continuous system is shown in Figure 1 .

For a batch system, chemical precipitation requires only a feed system for the treatment chemicals and a second tank where the waste can be treated and allowed to settle. When lime is used, it is usually added to the reaction tank in a slurry form. In a batch system, the supernate is usually analyzed before discharge, thus minimizing the need for instrumentation.

In a continuous system, additional tanks are necessary, as well as instrumentation to ensure that the system is operating properly. In this system, the first tank that the wastewater enters is referred to as an equalization tank. This is where the waste can be mixed in order to provide more uniformity, minimizing wide swings in the type and concentration of constituents being sent to the reaction tank. It is important to reduce the variability of the waste sent to the reaction tank because control systems inherently are limited with regard to the maximum fluctuations that can be managed.

Following equalization, the waste is pumped to a reaction tank where treatment chemicals are added; this is done automatically by using instrumentation that senses the pH of the system and then pneumatically adjusts the position of the treatment chemical feed valve such that the

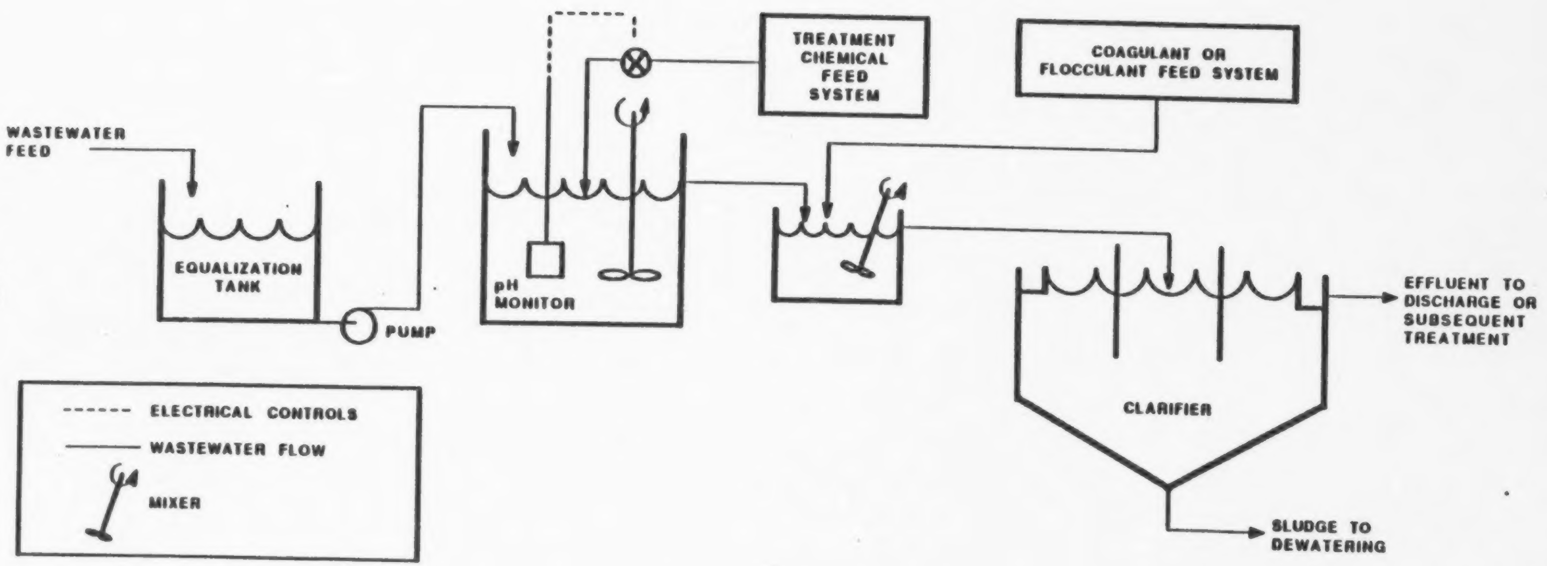

WASTEWATER FEED
EQUALIZATION TANK
PUMP
pH MONITOR
TREATMENT CHEMICAL FEED SYSTEM
COAGULANT OR FLOCCULANT FEED SYSTEM
CLARIFIER
EFFLUENT TO DISCHARGE OR SUBSEQUENT TREATMENT
SLUDGE TO DEWATERING
------ ELECTRICAL CONTROLS
WASTEWATER FLOW
MIXER

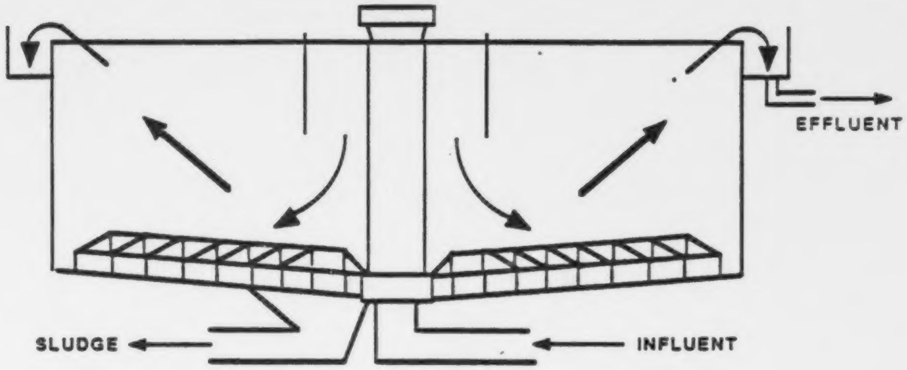
FIGURE 1. CONTINUOUS CHEMICAL PRECIPITATION

design pH value is achieved. Both the complexity and the effectiveness of the automatic control system will vary depending on the variation in the waste and the pH range that is needed to properly treat the waste.

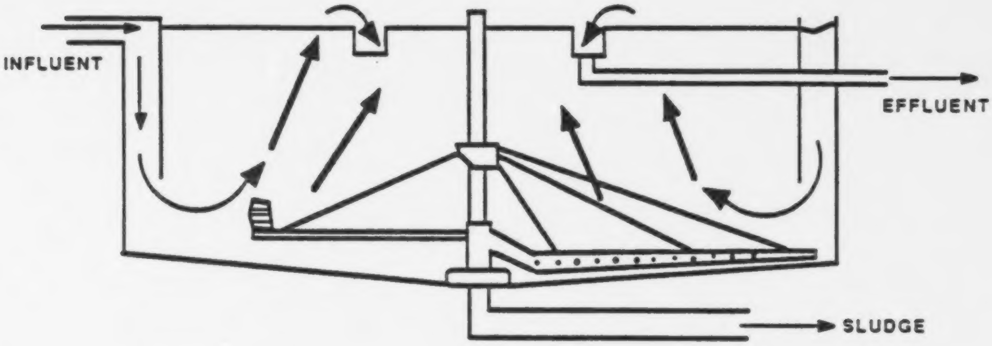
An important aspect of the reaction tank design is that it be well-mixed so that the waste and the treatment chemicals are both dispersed throughout the tank, in order to ensure comingling of the reactant and the treatment chemicals. In addition, effective dispersion of the treatment chemicals throughout the tank is necessary to properly monitor and, thereby, control the amount of treatment chemicals added.

After the waste is reacted with the treatment chemical, it flows to a quiescent tank where the precipitate is allowed to settle and subsequently be removed. Settling can be chemically assisted through the use of flocculating compounds. Flocculants increase the particicle size and density of the precipitated solids, both of which increase the rate of settling. The particular flocculating agent that will best improve settling characteristics will vary depending on the particular waste; selection of the flocculating agent is generally accomplished by performing laboratory bench tests. Settling can be conducted in a large tank by relying solely on gravity or be mechanically assisted through the use of a circular clarifier or an inclin~~d~~ed separator. Schematics of the latter two separators are shown in Figures 2 and 3.

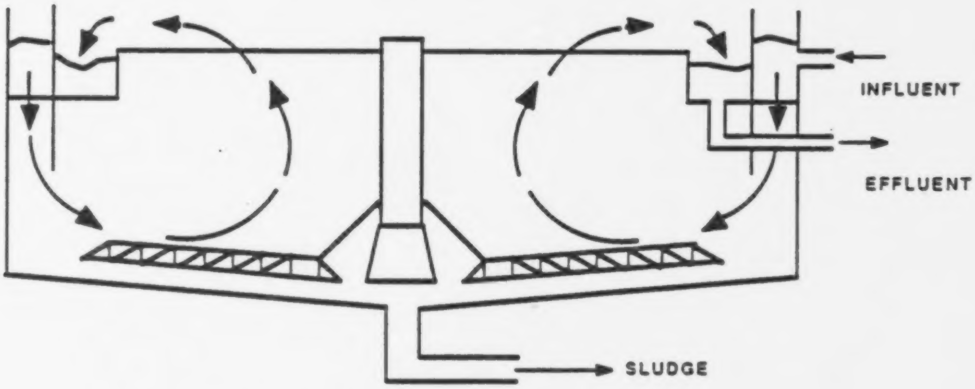
Filtration can be used for further removal of precipitated residuals both in cases where the settling system is underdesigned and in cases where the particles are difficult to settle. Polishing filtration is discussed in a separate technology section.


EFFLUENT
SLUDGE
INFLUENT

CENTER FEED CLARIFIER WITH SCRAPER SLUDGE REMOVAL SUSTEM

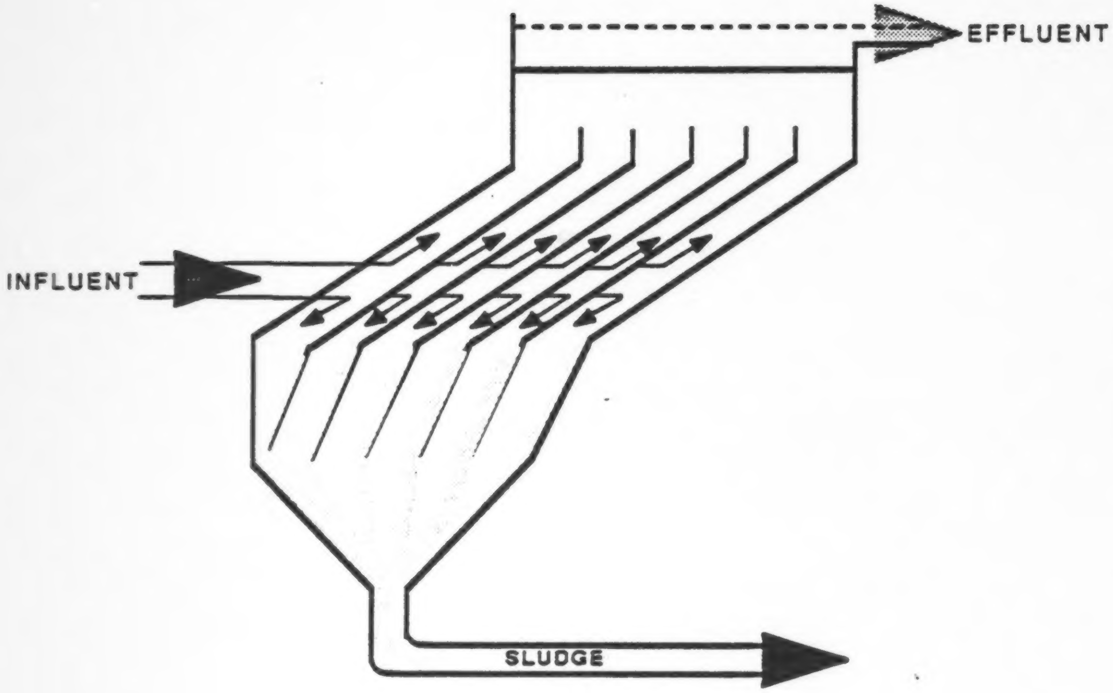

INFLUENT
EFFLUENT
SLUDGE

RIM FEED - CENTER TAKEOFF CLARIFIER WITH
HYDRAULIC SUCTION SLUDGE REMOVAL SYSTEM


INFLUENT
EFFLUENT
SLUDGE

RIM FEED - RIM TAKEOFF CLARIFIER

FIGURE 2
CIRCULAR CLARIFIERS



EFFLUENT
INFLUENT
SLUDGE

FIGURE 3
INCLINED PLATE SETTLER

Waste Characteristics Affecting Performance

In determining whether chemical preciptation is likely to achieve the same level of performance on an untested waste as a previously tested waste, we will examine the following waste characteristics: (1) the concentration and type of the metal(s) in the waste, (2) the concentration of suspended solids (TSS), (3) the concentration of dissolved solids (TDS), (4) whether the metal exists in the wastewater as a complex, and (5) the oil and grease content. These parameters either affect the chemical reaction of the metal compound, the solubility of the metal precipitate, or the ability of the precipitated compound to settle.

(1) Concentration and type of metals. For most metals, there is a specific pH at which the metal hydroxide is least soluble. As a result, when a waste contains a mixture of many metals, it is not possible to operate a treatment system at a single pH which is optimal for the removal of all metals. The extent to which this affects treatment depends on the particular metals to be removed, and their concentrations. An alternative can be to operate multiple precipitations, with intermediate settling, when the optimum pH occurs at markedly different levels for the metals present. The individual metals and their concentrations can be measured using EPA Method 6010.

(2) Concentration and type of total suspended solids (TSS). Certain suspended solid compounds are difficult to settle because of either their particle size or shape. Accordingly, EPA will evaluate this

characteristic in assessing transfer of treatment performance. Total suspended solids can be measured by EPA Wastewater Test Method 160.2.

(3) Concentration of total dissolved solids (TDS). Available information shows that total dissolved solids can inhibit settling. The literature states that poor flocculation is a consequence of high TDS and shows that higher concentrations of total suspended solids are found in treated residuals. Poor flocculation can adversely affect the degree to which precipitated particles are removed. Total dissolved solids can be measured by EPA Wastewater Test Method 160.1.

(4) Complexed metals. Metal complexes consist of a metal ion surrounded by a group of other inorganic or organic ions or molecules (often called ligands). In the complexed form, the metals have a greater solubility and, therefore, may not be as effectively removed from solution by chemical precipitation. EPA does not have an analytical method to determine the amount of complexed metals in the waste. The Agency believes that the best measure of complexed metals is to analyze for some common complexing compounds (or complexing agents) generally found in wastewater for which analytical methods are available. These complexing agents include ammonia, cyanide, and EDTA. The analytical method for cyanide is EPA Method 9010. The method for EDTA is ASTM Method D3113. Ammonia can be analyzed using EPA Wastewater Test Method 350.

(5) Oil and grease content. The oil and grease content of a particular waste directly inhibits the settling of the precipitate. Suspended oil droplets float in water and tend to suspend particles such

as chemical precipitates that would otherwise settle out of the solution. Even with the use of coagulants or flocculants, the separation of the precipitate is less effective. Oil and grease content can be measured by EPA Method 9071.

Design and Operating Parameters

The parameters that EPA will evaluate when determining whether a chemical precipitation system is well designed are: (1) design value for treated metal concentrations, as well as other characteristics of the waste used for design purposes (e.g., total suspended solids), (2) pH, (3) residence time, (4) choice of treatment chemical, and (5) choice of coagulant/flocculant. Below is an explanation of why EPA believes these parameters are important to a design analysis; in addition, EPA explains why other design criteria are not included in EPA's analysis.

(1) Treated and untreated design concentrations. EPA pays close attention to the treated concentration the system is designed to achieve when determining whether to sample a particular facility. Since the system will seldom out-perform its design, EPA must evaluate whether the design is consistent with best demonstrated practice.

The untreated concentrations that the system is designed to treat are important in evaluating any treatment system. Operation of a chemical precipitation treatment system with untreated waste concentrations in excess of design values can easily result in poor performance.

(2) pH. The pH is important, because it can indicate that sufficient treatment chemical (e.g., lime) is added to convert the metal

constituents in the untreated waste to forms that will precipitate. The pH also affects the solubility of metal hydroxides and sulfides, and therefore directly impacts the effectiveness of removal. In practice, the design pH is determined by empirical bench testing, often referred to as "jar" testing. The temperature at which the "jar" testing is conducted is important in that it also affects the solubility of the metal precipitates. Operation of a treatment system at temperatures above the design temperature can result in poor performance. In assessing the operation of a chemical precipitation system, EPA prefers continuous data on the pH and periodic temperature conditions throughout the treatment period.

(3) Residence time. The residence time is important because it impacts the completeness of the chemical reaction to form the metal precipitate and, to a greater extent, amount of precipitate that settles out of solution. In practice, it is determined by "jar" testing. For continuous systems, EPA will monitor the feed rate to ensure that the system is operated at design conditions. For batch systems, EPA will want information on the design parameter used to determine sufficient settling time (e.g., total suspended solids).

(4) Choice of treatment chemical. A choice must be made as to what type of precipitating agent (i.e., treatment chemical) will be used. The factor that most affects this choice is the type of metal constituents to be treated. Other design parameters, such as pH, residence time, and choice of coagulant/flocculant agents, are based on the selection of the treatment chemical.

(5) Choice of coagulant/flocculant. This is important because these compounds improve the settling rate of the precipitated metals and allows for smaller systems (i.e., lower retention time) to achieve the same degree of settling as a much larger system. In practice, the choice of the best agent and the required amount is determined by "jar" testing.

(6) Mixing. The degree of mixing is a complex assessment which includes, among other things, the energy supplied, the time the material is mixed, and the related turbulence effects of the specific size and shape of the tank. EPA will, however, consider whether mixing is provided and whether the type of mixing device is one that could be expected to achieve uniform mixing. For example, EPA may not use data from a chemical precipitation treatment system where an air hose was placed in a large tank to achieve mixing.

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APPENDIX G

SLUDGE FILTRATION

This Appendix, consisting of a description of the sludge filtration treatment technology, includes information relevant to the use and understanding of the background document for the K011, K013, and K014 listed hazardous wastes subject to the RCRA "Land Ban" restrictions.

It is anticipated that non-substantive changes will be made to this treatment technology description prior to publication of final "Second Thirds" Land Ban regulations. These changes will be primarily formatting and organizational in nature.

APPENDIX G

Technology - Sludge Filtration

Applicability

Sludge filtration, also known as sludge dewatering or cake-formation filtration, is a technology used on wastes that contain high concentrations of suspended solids, generally higher than one percent. The remainder of the waste is essentially water. Sludge filtration is applied to sludges, typically those that have settled to the bottom of clarifiers, for dewatering. After filtration, these sludges can be dewatered to 20 to 50 percent solids.

Underlying Principle of Operation

The basic principle of filtration is the separation of particles from a mixture of fluids and particles by a medium that permits the flow of the fluid but retains the particles. As would be expected, larger particles are easier to separate from the fluid than smaller particles. Extremely small particles, in the colloidal range, may not be filtered effectively and may appear in the treated waste. To mitigate this problem, the wastewater should be treated prior to filtration to modify the particle size distribution in favor of the larger particles, by the use of appropriate precipitants, coagulants, flocculants, and filter aids. The selection of the appropriate precipitant or coagulant is important because it affects the particles formed. For example, lime neutralization usually produces larger, less gelatinous particles than does caustic soda precipitation. For larger particles that become too small to filter effectively because of poor resistance to shearing, shear resistance can be improved by the use of coagulants and flocculants. Also, if pumps are used to feed the filter, shear can be minimized by designing for a lower pump speed, or by use of a low shear type of pump.

Technology Description

For sludge filtration, settled sludge is either pumped through a cloth-type filter media (such as in a plate and frame filter that allows solid "cake" to build up on the media) or the sludge is drawn by vacuum through the cloth media (such as on a drum or vacuum filter, which also allows the solids to build). In both cases the solids themselves act as a filter for subsequent solids removal. For a plate and frame type filter, removal of the solids is accomplished by taking the unit off line, opening the filter and scraping the solids off. For the vacuum type filter, cake is removed continuously. For a specific sludge, the plate and frame type filter will usually produce a drier cake than a vacuum filter. Other types of sludge filters, such as belt filters, are also used for effective sludge dewatering.

Waste Characteristics Affecting Performance

The following characteristics of the waste will affect performance of a sludge filtration unit:

- size of particles and
- type of particles.

(i) Size of particles - The smaller the particle size, the more the particles tend to go through the filter media. This is especially true for a vacuum filter. For a pressure filter (like a plate and frame), smaller particles may require higher pressures for equivalent throughput, since the smaller pore spaces between particles create resistance to flow.

(ii) Type of particles - Some solids formed during metal precipitation are gelatinous in nature and cannot be dewatered well by cake-formation filtration. In fact, for vacuum filtration a cake may not form at all. In most cases solids can be made less gelatinous by use of the appropriate coagulants and coagulant dosage prior to clarification, or after clarification but prior to filtration. In addition, the use of lime instead of caustic soda in metal precipitation will reduce the formation of gelatinous solids. Also the addition of filter aids to a gelatinous sludge, such as lime or diatomaceous earth, will help significantly. Finally, precoating the filter with diatomaceous earth prior to sludge filtration will assist in dewatering gelatinous sludges.

Design and Operating Variables that Affect Performance

For sludge filtration, the following design and operating variables affect performance:

- type of filter selected,
- size of filter selected,
- feed pressure, and
- use of coagulants or filter aids.

(i) Type of filter - Typically, pressure type filters (such as a plate and frame) will yield a drier cake than a vacuum type filter and will also be more tolerant of variations in influent sludge characteristics. Pressure type filters, however, are batch operations, so that when cake is built up to the maximum depth physically possible (constrained by filter geometry), or to the maximum design pressure, the filter is turned off while the cake is removed. A vacuum filter is a continuous device (i.e., cake discharges continuously), but will usually be much larger than a pressure filter with the same capacity. A hybrid device is a belt filter, which mechanically squeezes sludge between two continuous fabric belts.

(ii) Size of filter - As with in-depth filters, the larger the filter, the greater its hydraulic capacity and the longer the filter runs between cake discharge.

(iii) Feed pressure - This parameter impacts both the design pore size of the filter and the design flow rate. It is important that in treating waste that the design feed pressure not be exceeded, otherwise particles may be forced through the filter medium resulting in ineffective treatment.

(iv) Use of coagulants - Coagulants and filter aids may be mixed with filter feed prior to filtration. Their effect is particularly significant for vacuum filtration in that it may make the difference in a vacuum filter between no cake and a relatively dry cake. In a pressure filter, coagulants and filter aids will also significantly improve hydraulic capacity and cake dryness. Filter aids, such as diatomaceous earth, can be precoated on filters (vacuum or pressure) for particularly difficult to filter sludges. The precoat layer acts somewhat like an in-depth filter in that sludge solids are trapped in the precoat pore spaces. Use of precoats and most coagulants or filter aids significantly increases the amount of sludge solids to be disposed of. However, polyelectrolyte coagulant usage usually does not increase sludge volume significantly because the dosage is low.

APPENDIX H

STABILIZATION OF METALS

This Appendix, consisting of a description of the stabilization treatment technology, includes information relevant to the use and understanding of the background document for the K011, K013, and K014 listed hazardous wastes subject to the RCRA "Land Ban" restrictions.

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APPENDIX H

Technology - Stabilization of Metals

Stabilization refers to a broad class of treatment processes that chemically reduce the mobility of hazardous constituents in a waste. Solidification and fixation are other terms that are sometimes used synonymously for stabilization or to describe specific variations within the broader class of stabilization. Related technologies are encapsulation and thermoplastic binding; however, EPA considers these technologies to be distinct from stabilization in that the operational principles are significantly different.

Applicability and Use of Stabilization

Stabilization is used when a waste contains metals that will leach from the waste when it is contacted by water. In general, this technology is applicable to wastes containing BDAT list metals, having a high filterable solids content, low TOC content, and low oil and grease content. This technology is commonly used to treat residuals generated from treatment of electroplating wastewaters. For some wastes, an alternative to stabilization is metal recovery.

Underlying Principles of Operation

The basic principle underlying this technology is that stabilizing agents and other chemicals are added to a waste in order to minimize the amount of metal that leaches. The reduced leachability is accomplished by the formation of a lattice structure and/or chemical bonds that bind the metals to the solid matrix and, thereby, limit the amount of metal constituents that can be leached when water or a mild acid solution comes into contact with the waste material.

There are two principal stabilization processes used; these are cement based and lime based. A brief discussion of each is provided below. In both cement-based or lime/pozzolan-based techniques, the stabilizing process can be modified through the use of additives, such as silicates, that control curing rates or enhance the properties of the solid material.

Portland Cement-Based Process

Portland cement is a mixture of powdered oxides of calcium, silica, aluminum, and iron, produced by kiln burning of materials rich in calcium and silica at high temperatures (i.e., 1400°C to 1500°C). When the anhydrous cement powder is mixed with water, hydration occurs and the cement begins to set. The chemistry involved is complex because many different reactions occur depending on the composition of the cement mixture.

As the cement begins to set, a colloidal gel of indefinite composition and structure is formed. Over a period of time, the gel swells and forms a matrix composed of interlacing, thin, densely-packed silicate fibrils. Constituents present in the waste slurry (e.g., hydroxides and carbonates of various heavy metals, are incorporated into the interstices of the cement matrix. The high pH of the cement mixture tends to keep metals in the form of insoluble hydroxide and carbonate salts.) It has been hypothesized that metal ions may also be incorporated into the crystal structure of the cement matrix, but this hypothesis has not been verified.

Lime/Pozzolan-Based Process

Pozzolan, which contains finely divided, noncrystalline silica (e.g., fly ash or components of cement kiln dust), is a material that is not cementitious in itself, but becomes so upon the addition of lime. Metals in the waste are converted to silicates or hydroxides which inhibit leaching. Additives, again, can be used to reduce permeability and thereby further decrease leaching potential.

Description of Stabilization Processes

In most stabilization processes, the waste, stabilizing agent, and other additives, if used, are mixed and then pumped to a curing vessel or area and allowed to cure. The actual operation (equipment requirements and process sequencing) will depend on several factors such as the nature of the waste, the quantity of the waste, the location of the waste in relation to the disposal site, the particular stabilization formulation to be used, and the curing rate.After curing, the solid formed is recovered from the processing equipment and shipped for final disposal.

In instances where waste contained in a lagoon is to be treated, the material should be first transferred to mixing vessels where stabilizing agents are added. The mixed material is then fed to a curing pad or vessel. After curing, the solid formed is removed for disposal. Equipment commonly used also includes facilities to store waste and chemical additives. Pumps can be used to transfer liquid or light sludge wastes to the mixing pits and pumpable uncured wastes to the curing site. Stabilized wastes are then removed to a final disposal site.

Commercial concrete mixing and handling equipment generally can be used with wastes. Weighing conveyors, metering cement hoppers, and mixers similar to concrete batching plants have been adapted in some operations. Where extremely dangerous materials are being treated, remote-control and in-drum mixing equipment, such as that used with nuclear waste, can be employed.

Waste Characteristics Affecting Performance

In determining whether stabilization is likely to achieve the same level of performance on an untested waste as on a previously tested waste, the Agency will focus on the characteristics that inhibit the formation of either the chemical bonds or the lattice structure. The four characteristics EPA has identified as affecting treatment performance are the presence of (1) fine particulates, (2) oil and grease, (3) organic compounds, and (4) certain inorganic compounds.

Fine Particulates

For both cement-based and lime/pozzolan-based processes, the literature states that very fine solid materials (i.e., those that pass through a No. 200 mesh sieve, 74 um particle size) can weaken the bonding between waste particles and cement by coating the particles. This coating can inhibit chemical bond formation and decreases the resistance of the material to leaching.

Oil and Grease

The presence of oil and grease in both cement-based and lime/pozzolan-based systems results in the coating of waste particles and the weakening of the bonding between the particle and the stabilizing agent. This coating can inhibit chemical bond formation and thereby, decrease the resistance of the material to leaching.

Organic Compounds

The presence of organic compounds in the waste interferes with the chemical reactions and bond formation which inhibit curing of the stabilized material. This results in a stabilized waste having decreased resistance to leaching.

Sulfate and Chlorides

The presence of certain inorganic compounds will interfere with the chemical reactions, weakening bond strength and prolonging setting and curing time. Sulfate and chloride compounds may reduce the dimensional stability of the cured matrix, thereby increasing leachability potential.

Accordingly, EPA will examine these constituents when making decisions regarding transfer of treatment standards based on stabilization.

Design and Operating Parameters

In designing a stabilization system, the principal parameters that are important to optimize so that the amount of leachable metal constituents is minimized are (1) selection of stabilizing agents and other additives, (2) ratio of waste to stabilizing agents and other additives, (3) degree of mixing, and (4) curing conditions.

(1) Selection of stabilizing agents and other additives. The stabilizing agent and additives used will determine the chemistry and structure of the stabilized material and, therefore, will affect the leachability of the solid material. Stabilizing agents and additives must be carefully selected based on the chemical and physical characteristics of the waste to be stabilized. For example, the amount of sulfates in a waste must be considered when a choice is being made between a lime/pozzolan and a Portland cement-based system.

In order to select the type of stabilizing agents and additives, the waste should be tested in the laboratory with a variety of materials to determine the best combination.

(2) Amount of stabilizing agents and additives. The amount of stabilizing agents and additives is a critical parameter in that sufficient stabilizing materials are necessary in the mixture to bind the waste constituents of concern properly, thereby making them less susceptible to leaching. The appropriate weight ratios of waste to stabilizing agent and other additives are established empirically by setting up a series of laboratory tests that allow separate leachate testing of different mix ratios. The ratio of water to stabilizing agent (including water in waste) will also impact the strength and leaching characteristics of the stabilized material. Too much water will cause low strength; too little will make mixing difficult and, more importantly, may not allow the chemical reactions that bind the hazardous constituents to be fully completed.

(3) Mixing. The conditions of mixing include the type and duration of mixing. Mixing is necessary to ensure homogeneous distribution of the waste and the stabilizing agents. Both undermixing and overmixing are undesirable. The first condition results in a nonhomogeneous mixture; therefore, areas will exist within the waste where waste particles are neither chemically bonded to the stabilizing agent nor physically held within the lattice structure. Overmixing, on the other hand, may inhibit gel formation and ion adsorption in some stabilization systems. As with the relative amounts of waste, stabilizing agent, and additives within the system, optimal mixing conditions generally are determined through laboratory tests. During treatment it is important to monitor the degree (i.e., type and duration) of mixing to ensure that it reflects design conditions.

(4) Curing conditions. The curing conditions include the duration of curing and the ambient curing conditions (temperature and humidity). The duration of curing is a critical parameter to ensure that the waste particles have had sufficient time in which to form stable chemical bonds and/or lattice structures. The time necessary for complete stabilization depends upon the waste type and the stabilization used. The performance of the stabilized waste (i.e., the levels of constituents in the leachate) will be highly dependent upon whether complete stabilization has occurred. Higher temperatures and lower humidity increase the rate of curing by increasing the rate of evaporation of water from the solidification mixtures. However, if temperatures are too high, the

evaporation rate can be excessive and result in too little water being available for completion of the stabilization reaction. The duration of the curing process should also be determined during the design stage and typically will be between 7 and 28 days.

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